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Endoparasitic Infestations in Grouse, Their Pathogenicity and Correlation With Meteoro-Topographical Conditions

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CONTENTS

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INTRODUCTION

Fluctuations in the numbers of game birds have attracted attention, both in Europe and North America, for at least two centuries. In England the fluctuations were probably much greater than those occurring in this country, owing to the artificial state of grouse farming, and this has resulted in a number of intensive investigations as to their cause.

In North America, one of the earliest references to the disappearance of the grouse is that of Edwards (1754) who reported the destruction of *Tetrao umbellus* in the lower settlements of Pennsylvania. This is our ruffed grouse, *Bonasa umbellus* Linnaeus. Whether this destruction was the result of shooting or some other cause is not exactly clear, but there is no doubt that fluctuations in numbers were recognized at an early date. In 1791 the State of New York passed a law providing for what was probably the first closed season on ruffed grouse on the American continent. In Minnesota the first closed season on ruffed grouse was established in 1871, and since that time the shooting of grouse has been regulated from time to time by state legislation.

Many explanations have been put forth as to the cause or causes of these fluctuations. In England, according to Leslie and Shipley (1911), "grouse disease" was first recognized in 1838. Cobbold (1873) described a new species of nematode, *Trichostrongylus pergracilis,* and attempted to show that the nematode was responsible for the epidemics among the English red grouse *(Logopus logopus scoticus).* In contrast to Cobbold's idea, Klein (1892) came to the conclusion that the disease in the red grouse took the form of an acute infectious pneumonia and was characterized by the presence in the lungs of a specific bacillus of the *Bacillus coli* group. The English investigation in 1911 showed clearly that epizootics in grouse were caused by *Trichostrongylus pergracilis* and coccidiosis, and that Klein's infectious pneumonia is not a disease separate and distinct from strongylosis. Portal and Collinge (1932) in a

[1] This study was made possible by the co-operation of the Division of Entomology and Economic Zoology, the University Department of Zoology, the Minnesota Conservation Department, and Dr. R. G. Green of the Medical School. It was carried out under the supervision of Dr. W. A. Riley, to whom acknowledgment is due for helpful suggestions, kind criticisms, and assistance in preparation of the manuscript.

Special acknowledgment is also due Dr. Dwight E. Minnich, Chairman of the Department of Zoology, and Dr. R. G. Green and Mr. Ralph T. King for aid in many ways throughout the course of the work. Dr. F. G. Wallace and Mr. C. G. Fredine autopsied a considerable number of the birds during the years 1931 and 1932, and technical assistance was given by Miss E. Bailey, Miss M. Sherva, and Mrs. G. Friedlund.

similar investigation in England into the causes of partridge epizootics found that *Trichostrongylus tenuis* and coccidiosis were the principal causes of the fluctuations in that country.

In this country, in contrast to the findings in England, no definite cause has been found to explain the fluctuations in population numbers of game birds, altho various factors have been ascribed. Many people have been of the opinion that the great mortality among old and young birds was due to coccidiosis. Others have suggested helminths of various kinds, diseases such as enteritis, pneumonia, and tularemia, vitamin deficiency, and climatic factors. In no case has any of the parasites or diseases suggested been found to cause a widespread epizootic among the game birds.

The present parasitological study includes both the ruffed grouse *(Bonasa umbellus* Linnaeus) and the sharp-tail grouse *(Pediocectes phasianellus campestris* Linnaeus), altho the ruffed grouse was the chief object of study, because it is not only the most common of the game birds in the northwest, but also fluctuates to a much greater extent than the sharp-tail grouse. The work was undertaken at a time when the grouse population of the northwest was building up to a maximum. The purpose of the investigation was to determine whether the parasites of the grouse are sufficiently pathogenic in nature to account for the fluctuations in population numbers, and to determine the factors responsible for the varying degrees of parasitism in different parts of the state.

The results put forward in this report are based upon an examination of 670 birds, 560 of which were ruffed grouse and 62 specimens of sharp-tail grouse. The remaining 48 were discarded for various reasons. The survey was carried on during the period August 1931 to January 1935, material being obtained from 23 counties in Minnesota and from South Dakota, Michigan, and Wisconsin.

The publication of the important findings of the British Grouse Investigation Committee, in 1911, stimulated workers to investigate the parasites and diseases of game birds in this country. A considerable number of investigations into the "parasites of grouse" have been undertaken in this country since 1920. Until the last few years, the majority of these parasitic investigations have been badly conducted and probably were carried on only as minor problems under larger game management projects.

Allen (1924) reported on a survey of 65 ruffed grouse, undertaken during 1923 in New England. He was the first to report the occurrence of *Acuaria (Dispharynx spiralis)* and suggested that it may possibly be the cause of "grouse disease" in this country. Of 65 birds examined, 14 were parasitized with *Dispharynx spiralis.* In 1925 he reported 11 birds out of 75 parasitized by this species. In 1924 he reported 120 out of 177 captive birds died of coccidiosis before they were two weeks old; 24 from blackhead between six to eight weeks old, and 10 from *Dispharynx.*

Stafseth and Kotlan (1925) in an examination of five birds from

Michigan were the first to report the presence of *Cheilospirura spinosa* in the gizzard, and small numbers of Trypanosomes in the blood.

Gross (1925) published data on autopsies of 17 ruffed grouse, and again in 1926 reported on an examination of 417 birds. Apparently all these data are included in a joint report by Allen and Gross (1926), in which the results of the examination of 923 specimens are given. For ruffed grouse this parasitological survey is the most extensive reported on in this country. Specimens were collected from 14 states in the Union and Canada. The conclusions that may be drawn from their report are:

1. Only 24 of the total were infested with *Dispharynx spiralis,* the species suggested by Allen (1924) as the cause of grouse disease, and all cases were restricted to New York, New Jersey, and Southern New England.

2. *Thominx annulata,* a nematode occurring beneath the epithelial lining of the crop, esophagus, and gullet was limited to Southern New England and Columbia County, New York.

3. The incidence of infestation with *Eimeria* was remarkably low, only one case being reported.

4. The incidence of infectious diseases was low, there being only 4 cases of enteritis; 1 of hepatitis; 7 of enterohepatitis (blackhead) in captive birds; 29 of bird pox; and 3 cases of aspergillosis in adults and 6 in young grouse.

5. There was a lack of any specific form of parasitism which would account for the fluctuations in the grouse population over wide areas.

Gross (1931) stated that during the five years 1926-1931, 2,000 specimens of ruffed grouse and prairie chicken were examined, but he published no data in this report. In 1930 he reported on an investigation of the "Wisconsin Prairie Chicken," giving a summary of the parasites found in 127 birds, including ruffed grouse, sharp-tail grouse, and prairie chicken, but he made no differentiation between the parasites of the different species of birds. Gross (1932), working in the New England states, concluded that *Dispharynx spiralis* had increased during the year 1931 but again gave no data.

Cram (1931a) published the results of an examination of 64 ruffed grouse from Labrador. Of the 31 birds infested, none harbored nematodes; 22 were infested with trematodes; 4 with cestodes, and 9 with coccidia. Bump (1935) stated that during the past two years 413 adult ruffed grouse were examined, no epidemics were encountered, and there had been a gradual increase in the incidence of parasites in general. During 1934, 169 birds were examined, varying in age from three hours to three months. He reported *Ascaridia* eggs were found in three-day-old chicks, but gave no explanation as to whether the eggs were swallowed by the birds, or produced by mature worms in the intestinal tract. Cestode scolices were found in partridge at the age of one week. Coccidia were common, 11 separate species being identified in the ruffed grouse. Saunders (1935) reported the occurrence of *Oxyspirura mansoni* in the ruffed grouse, sharp-tail grouse, and prairie chicken of Michigan.

Tyzzer (1929) reported the occurrence of *Eimeria dispersa* in the ruffed grouse, and Allen (1934) published descriptions of two new species of *Eimeria,* namely, *E. bonasae* and *E. angusta,* in the ruffed grouse.

Tyzzer (1930) reported the occurrence of two new species of flagellates in the ruffed grouse but states: "Insofar as it is possible to determine, these two flagellates do not affect the health of the grouse since they occur in plump, healthy appearing specimens." Clarke (1934) pointed out that the disappearance of young grouse in Ontario, Canada, was associated with a very high occurrence of a Leucocytozoan. He states: "A mortality of at least 60 per cent among chicks had taken place to mid-July in the area under immediate observation, and in practically all specimens examined, adult and young, the Leucocytozoan was found to be present. In view of the fact that similar parasites are known to be lethal to ducks and turkeys, a connection between its occurrence in grouse and the high mortality observed is suspected." Clark (1935) named this parasite *Leucocytozoan bonasae* and pointed out that altho this was the only significant parasite found, it has not been proved that it is capable of killing a grouse. Saunders (1935) referred to the presence of a Leucocytozoan in several sharp-tail grouse and ruffed grouse from Michigan.

Materials and Methods

The major problem in the survey was to procure such a number of birds that definite conclusions could be made from the data obtained. The work was carried on in conjunction with Dr. R. G. Green and Mr. R. T. King of the University of Minnesota. Dr. Green is primarily interested in the diseases of upland game birds and rodents, while Mr. King has been interested in game fluctuations and game management for a number of years. Specimens were procured through co-operation with the Minnesota Department of Game and Fish from various game wardens throughout the state.

The ideal survey, of course, should consist of a monthly examination of a number of birds from a large number of localities representing the whole of the state. An alternative method is the monthly examination of as many specimens as possible from just one locality. When the area of the state, which occupies 84,682 square miles, is considered, it is obvious that the latter method is unsuitable, owing to the impossibility of selecting one locality topographically typical of the whole area.

Taking into consideration, therefore, the size of the state and the difficulty of procuring birds in the southern part, it was considered best to restrict the survey to the northern half of the state, an area of approximately 45,000 square miles, and to make a number of examinations from a limited number of locations during the period of the survey. The specimens obtained from neighboring states were sent in to Dr. Green and passed through the writer's hands as a part of the general routine work.

During the course of the survey it was impossible to procure material at regular intervals from the same area. As a result, the incidence

of infestation of a particular area has in many cases been determined for only one period of the survey. During the summer months of June, July, and August, specimens could not be sent in for examination. Hunting during those months is more difficult, due to the increased vegetation, and usually game wardens refuse to shoot birds during the breeding season or while the birds remain together in coveys.

The autopsies consisted of a systematic search of all the organs for helminth parasites. The examination of the digestive tract was facilitated by forcing tap water through the gut and decanting the washed-out debris. In the centrifugal examination of fecal material for eggs and coccidial cysts, a solution of 50 grams of cane sugar to 50 cubic centimeters of water was used. Parasitic infestation could not be determined with certainty during the winter by means of fecal tests; apparently egg laying is at a minimum during that period.

In the examination, material was removed as soon as possible after the bird was killed. Cestodes were washed in water, stretched upon a glass plate, and painted with a 10 per cent solution of formalin raised to a temperature of 80° C. Another excellent method of fixing cestodes was to flood them while *in situ,* with water at a temperature of 70° C. By either method, the cestodes were fixed in a fully extended condition. The material was preserved in either 5 per cent formalin or 70 per cent alcohol. The nematodes were fixed in 70 per cent alcohol and 5 per cent glycerol raised to the boiling point.

The best stain for the cestode material was cochineal (the concentration of the solution depending upon the species to be stained). Differentiation was often found necessary. Sections were stained with Erlich's hematoxlin and eosin. The cestodes were cleared in oil of wintergreen, while the nematodes were examined in glycerol.

THE PARASITIC FAUNA

The helminths recorded in this bulletin comprise four species of cestoda, seven of nematoda, and two of trematoda. The protozoan genus *Eimeria* was represented by several species. No attempt was made to find other species of protozoa that might have been present. The parasites found may be listed as follows:

Cestoda

Fam. Davaineidae Fuhrmann, 1907

Davainea proglottina (Davaine, 1860) Blanchard, 1891

Raillietina (Raillietina) tetragona (Molin, 1858) Joyeux, 1927

Fam. Dilepididae Fuhrmann, 1907

Choanotaenia infundibulum (Bloch, 1779) Cohn, 1899

Rhabdometra nullicollis Ransom, 1909

Nematoda

Fam. Ascaridae Baird, 1853

Ascaridia lineata (Schneider, 1866) Railliet and Henry, 1914

Fam. Heterakidae Railliet and Henry, 1914

Heterakis gallinae (Gmelin, 1790) Freeborn, 1923

Fam. Subuluridae York and Maplestone, 1925
Subulura strongylina (Rudolphi, 1819) Railliet and Henry, 1914
Fam. Acuriidae Seurat, 1913
Cheilospirura spinosa Cram, 1927
Fam. Spiruridae Oerley, 1885
Seurocyrnea colini (Cram, 1927) Strand, 1929
Fam. Thelaziidae Railliet, 1916
Oxyspirura mansoni (Cobbold, 1879) Ransom, 1904
Fam. Physalopteridae Leiper, 1908
Physaloptera sp. larva. Rudolphi, 1819
Trematoda
Fam. Strigidae Railliet, 1919
Agamodistomum sp.
Subfam. Harmostominae Braun, 1900
Harmostomum (Harmostomum) pellucidum Werby, 1928
Protozoa
Fam. Eimeriidae
Eimeria dispersa Tyzzer, 1929
Eimeria angusta Allen, 1934

Davainea proglottina (Davaine, 1860) Blanchard, 1891

SYNONYMS.—*Taenia proglottina* Davaine, 1860; *Davainea proglottina* Blanchard, 1891; *Davainea p. var. dublanensis* Kowalawski, 1895; *Davainea varians* Sweet, 1910; *Davainea dubius* Meggit, 1916.

HOSTS.—Primary, *Gallus domesticus, Bonasa umbellus;* secondary, *Limax flavus, Agriolimax agrestis, Limax cinereus, L. variegatus.*

LOCATION.—Small intestine.

MORPHOLOGY.—Length 0.5 to 1.55 mm. long by 0.18 to 0.50 mm. broad. Head club-shaped to quadrangular, 140 to 250 μ long to 200 μ broad, rather rounded in front and slightly constricted in back to form a neck, approximately 108 μ broad; rostellum 55 μ in its antero-posterior diameter and 60 to 85 μ in its lateral diameter; base of the rostellum armed with about 80 to 95 hooklets measuring 6.5 to 8.1 μ. Suckers circular 25 to 35 μ, armed with a single row of hooklets 6 μ long with rather bilobed base. Strobila composed of from two to five segments, first segment only about 56 μ long, the following segments increasing in length and width. Genital pores irregularly alternate, situated at the anterior angle. In the third segment the testes and female organs are well developed (median posterior vitellarium, two ovaries, recpt. sem., vagina). In the fourth segment all the glands are atrophied, and the segment is filled with numerous isolated eggs (not in egg capsules); ova 35 to 40 μ; hooks of the oncosphere 10 to 11 μ. The last segment may separate completely from the rest of the worm and remain in the intestine, where it may grow to a length of 2 mm. long by 1.25 mm. broad.

DISTRIBUTION.—Europe and North America. In Minnesota, this parasite was found in only three birds, but due to its small size it could easily have been overlooked in a light infestation.

Raillietina (Raillietina) tetragona (Molin, 1858) Joyeux, 1927

SYNONYMS.—*Taenia t.* Molin, 1858; *T. bothrioplitis Filippi,* 1892, (nec Piana); *Davainea t.* Blanchard, 1891, (ex part) Stiles 1896, (ex part) Ransom, 1904, Lopez-Neyra, 1920; *Raillietina t.* Lang, 1929; *Kotlania t.* Lopez-Neyra, 1931.

HOSTS.—Primary, *Bonasa umbellus, Colinus virginianus, Gallus gallus, Meleagris gallopavo, Numida meleagris;* secondary, *Helix sp., Musca domestica.*

LOCATION.—Small intestine, occasionally in ceca.

MORPHOLOGY.—Ten to 250 mm. long by 1 to 4 mm. broad. Head 175 to 350 μ in diameter, with retractile rostellum 30 to 75 μ in diameter, armed with a crown of about 100 hooks arranged in a single row. Suckers oval 50 to 150 μ in diameter, armed with 8 to 12 rows of hooks. Rostellar hooks 6 to 8 μ long through the longest axis, with long thorn-like prong, dorsal root very short, ventral root longer than dorsal root, but shorter than the prong. Neck usually long and slender. Segments trapezoidal and imbricate. Genital pores irregularly alternate, at or in front of the middle of the lateral margin, male and female canals pass dorsal to the nerve and excretory vessels.

Testes 18 to 35 in the median field surrounding the female glands, most of them on the aporose side of the latter. Vas deferens lies in the anterior third of the segment, begins near the median line, and extends in a much

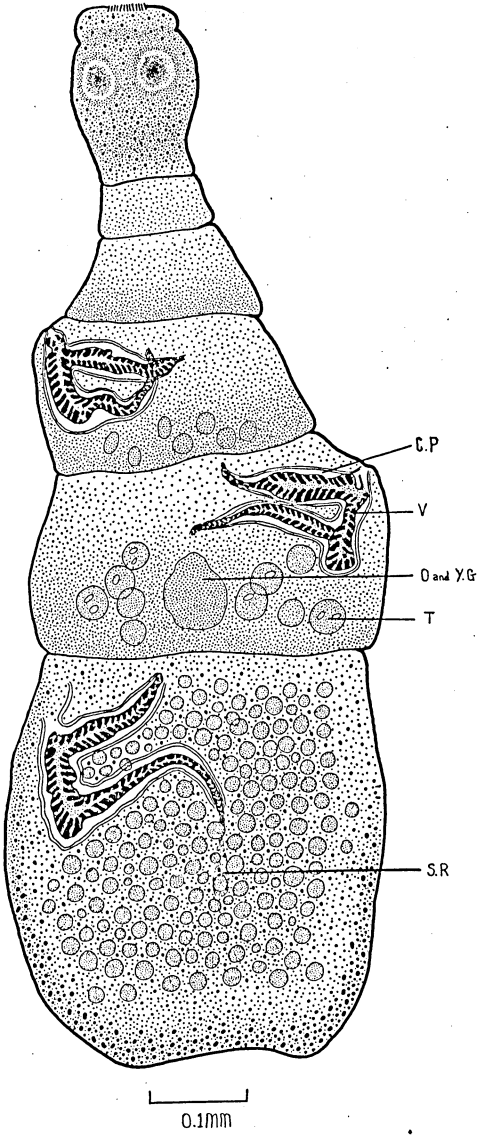


FIG. 1. DAVAINEA PROGLOTTINA
C. P. Cirrus pouch
O. and Y. G. Ovary and yolk gland
S. R. Seminal receptacle
T. Testis
V. Vagina

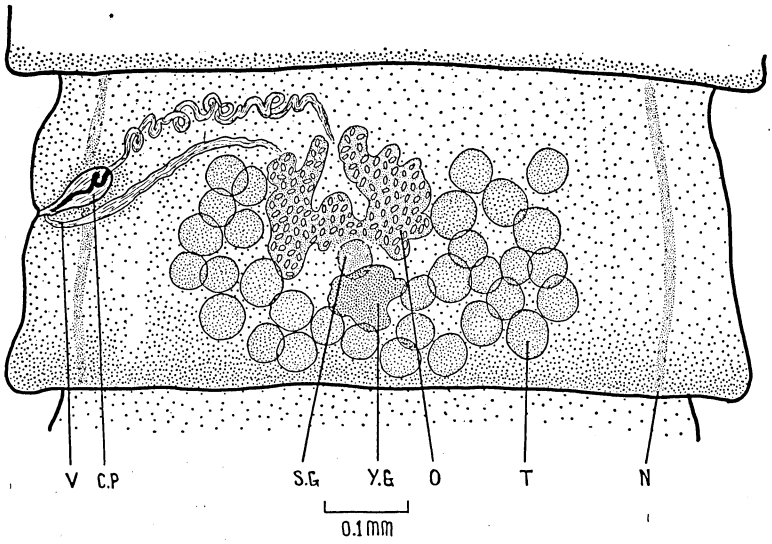


FIG. 2. RAILLIETINA TETRAGONA, MATURE PROGLOTTID

C. P. Cirrus pouch
N. Nerve
O. Ovary
S. G. Shell gland
T. Testis
V. Vagina
Y. G. Yolk gland

convulated course to the base of the cirrus pouch. Cirrus pouch pyriform, 60 to 100 μ in length, thickness of the muscle layer 4 to 6 μ. Cirrus without apparent spines.

Ovary in the middle of the segment. Yolk gland posterior of the ovary, irregular in shape, about 100 μ in diameter. Shell gland prominent, 50 μ in diameter, immediately in front of the yolk gland. Vagina begins at the genital pore posterior of the opening of the cirrus pouch, at first very slender, but at a distance of 15 to 25 μ swells out into a thin walled tube, functioning as a seminal receptacle, which extends transversely across the segment, and joins the oviduct on the dorsal side of the ovary. A definite and persistent uterus is not developed. Six to 12 or more eggs in each egg capsule. The egg is surrounded by three envelopes, an inner close to the oncosphere, a middle folded, and a smooth outer envelope. The oncosphere measures 10 to 14 μ in diameter, the outer envelope 25 to 50 μ.

DISTRIBUTION.—Europe, Asia, North and South America. In Minnesota identification of this species was only certain with material from young ruffed grouse. Five out of 14 young birds from Carlton County, ranging in age from a few hours to 10 days, were found infested.

This worm is closely related to *R. echinobothrida* and, no doubt, has been misidentified in many cases. The writer has differentiated the 2 species mainly on the number of testes and the size of the cirrus pouch.

Choanotaenia infundibulum (Bloch, 1779) Cohn, 1899

SYNONYMS.—*Taenia i.* Bloch, 1779; *T. infundibuliformis* Goeze, 1782; *Choanotaenia infundibuliformis* Lucet and Marotel, 1904; *Depanidotaenia i.* Stossich, 1895; *Taenia lagenicollis* Megnin, 1898, Blanchard, 1899; *Choanotaenia infundibulum* Cohn, 1899, 1901, *Monopylidium i.* Clerc, 1903.

HOSTS.—Primary, *Bonasa umbellus, Gallus gallus, Phasianus colchicus, Coturnix coturnix, Pedioecetes phasianellus campestris;* secondary, Ransom (1905) reports *Musca domestica* acting as the intermediate host for this species of cestode. Joyeux (1923) demonstrated experimentally that *Geotrupes sylvaticus* acts as an intermediate host. Jones (1930) suggested that cysts found in a ground beetle, *Cratacanthus dubius,* belonged to *Choanotaenia infundibulum,* but negative results were obtained when the beetle was fed to a chicken.

LOCATION.—Small intestine.

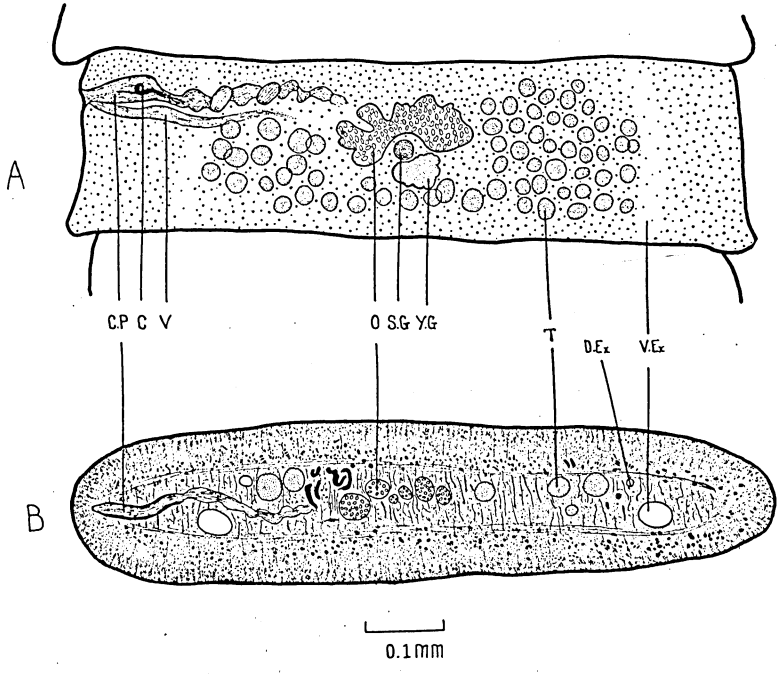


FIG. 3. CHOANOTAENIA INFUNDIBULUM

A. Mature proglottid
B. Transverse section of mature proglottid

C. P. Cirrus pouch
C. Cirrus
D. Ex. Dorsal excretory canal
O. Ovary
S. G. Shell gland
T. Testis
V. Vagina
V. Ex. Ventral excretory canal
Y. G. Yolk gland

MORPHOLOGY.—Length 50 to 200 mm. Scolex small, rounded or conoidal, about 0.4 mm. wide. Rostellum 60 to 70 μ in diameter, armed with a single row of 16 to 20 hooks 25 to 30 μ long, with long dorsal root, and short ventral root. Suckers prominent, elongated anteroposteriorly, length 180 to 210 μ by 135 to 175 μ between the extreme outer edges. Neck short and unsegmented, somewhat narrower than broad. Genital pores irregularly alternating, in the anterior third of the lateral margin. Vas deferens and vagina pass between the excretory canals and dorsal to the nerve trunk.

Testes 25 to 60 in the posterior half of the proglottid, posterior and lateral to the yolk gland, within limits of the excretory canals. Vas deferens passes forward and in the anterior third of the proglottid, forming a mass of coils. Cirrus pouch ovoid in shape, 75 to 95 μ in length.

Vagina posterior to the cirrus pouch, after crossing the ventral excretory canal dilated to form the ovoid seminal receptacle. Shell gland 40 to 50 μ in diameter; ovary is transversely elongated and lies in front of the shell gland. Large yolk gland posterior to the ovary and shell gland, irregular in shape. Gravid uterus fills up most of the proglottid, extending beyond the excretory canals on each side. Eggs oval, diameter of the outer membrane 60 to 65 μ by 40 to 45 μ. Embryonal hooks 18 μ long. Embryo 22 to 32 μ in diameter.

DISTRIBUTION.—Cosmopolitan. In Minnesota this species was the common cestode found, making up at least 75 per cent of the total cestode infestation. It appears to be distributed over the entire area of the survey.

Rhabdometra nullicollis Ransom, 1909

HOSTS.—Primary, *Centrocercus urophasianus, Pediocetes phasianellus campestris.*

MORPHOLOGY.—Length 50 to 100 mm. by 2 to 2.5 mm. broad. Head is obtusely pointed anteriorly, 560 to 650 μ wide, about 360 μ thick and 280 to 330 μ long, without rostellum. The suckers are 140 to 160 μ in diameter. The segments are at first the same width as the head, or slightly wider, and gradually increase in width, finally decreasing again at the posterior end of the strobila. Mature segments much broader than long, the gravid segments being much longer than broad. Sexual pores are irregularly alternate, located in the anterior third of the segment. Longitudinal muscles are arranged in numerous small bundles disposed in 2 layers close together, and a considerable distance from the surface of the segment. Dorso-ventral fibers are numerous, transverse fibers are few.

Testes number about 60, occurring in the posterior portion of the segment. They measure from 80 to 100 μ when fully developed. Cirrus pouch is elongated, broadest near the base, measuring 350 to 380 μ in length by 80 to 100 μ in thickness. Cirrus about 10 μ in diameter when evaginated, and from 250 to 350 μ in length. Muscular bulb of the vagina located close to the genital sinuses and measures 25 to 30 μ in

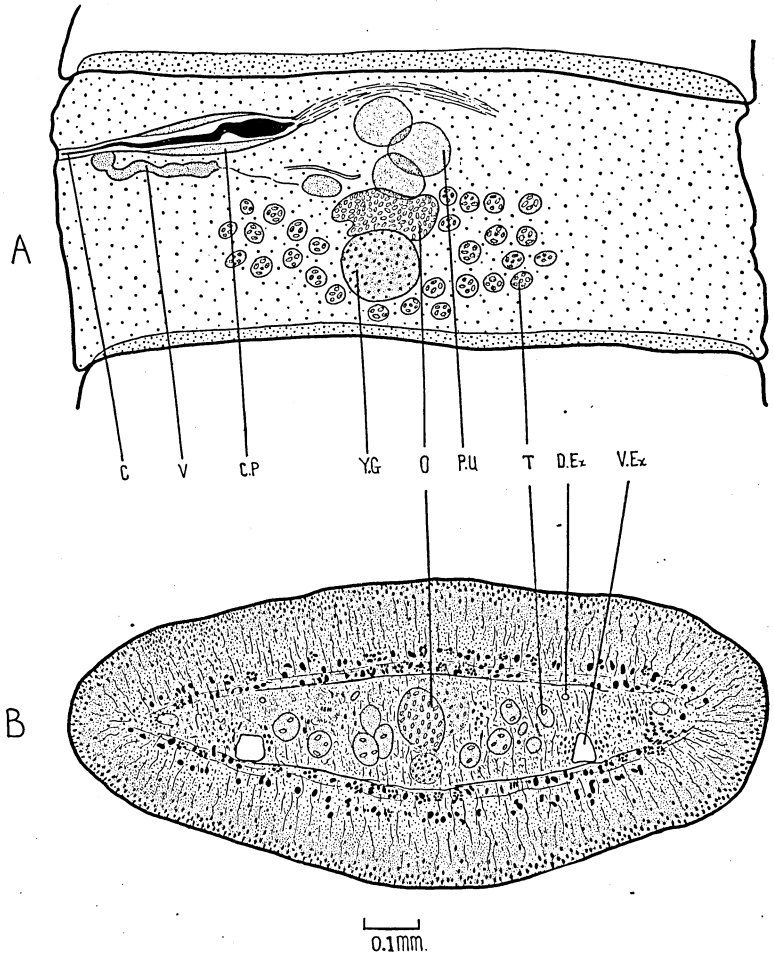


FIG. 4. RHABDOMETRA NULLICOLLIS

A. Mature proglottid
B. Transverse section of mature proglottid

C. Cirrus
C. P. Cirrus pouch
D. Ex. Dorsal excretory canal
O. Ovary
P. U. Para-uterine organ
T. Testis
V. Vagina
V. Ex. Ventral excretory canal
Y. G. Yolk gland

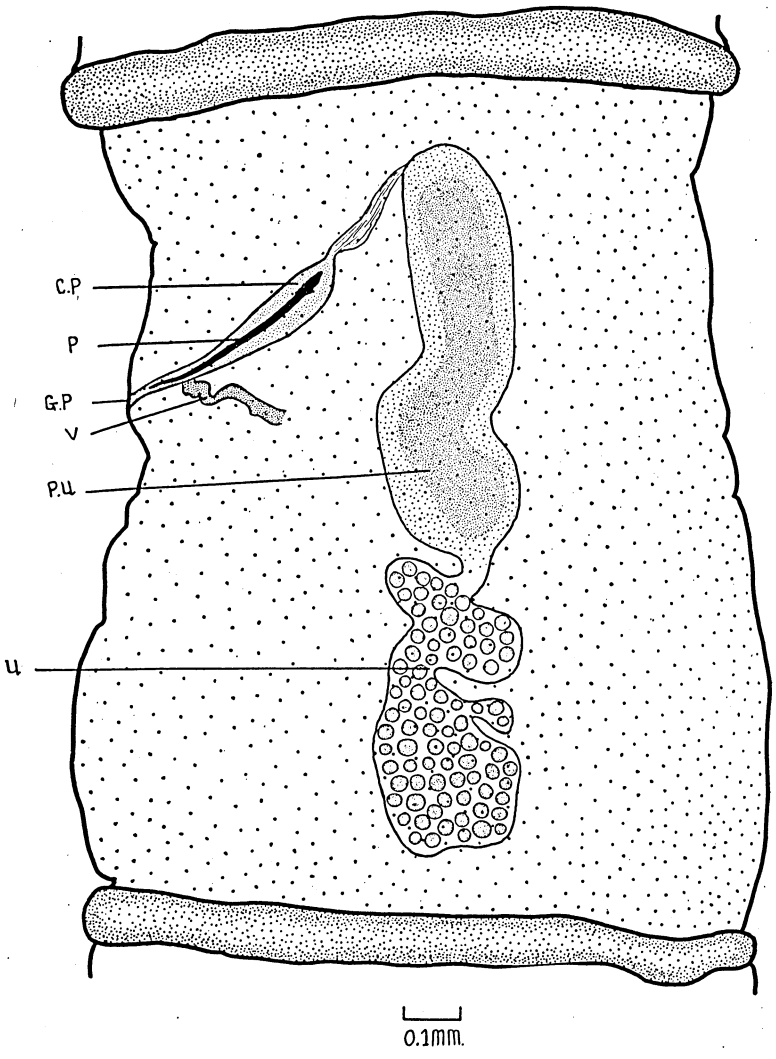


FIG. 5. RHABDOMETRA NULLICOLLIS, GRAVID PROGLOTTID

C. P. Cirrus pouch
G. P. Genital pore
P. Penis
P. U. Para-uterine organ
U. Uterus
V. Vagina

diameter, seminal receptacle about 50 μ wide by 75 to 100 μ long. Ovary is compact, never exceeding 175 μ in width. Yolk gland, which occurs posterior to the ovary, measures 100 to 130 μ in diameter. Dorsal of the yolk gland is the shell gland, slightly smaller. Uterus develops in front of and dorsal of the ovary, as a simple sac-like organ. The parenchyma in front of the uterus develops into a prominent para-uterine organ. Eggs are oval, with a thin outer membrane 36 to 46 μ in diameter, a thick middle shell 24 to 27 μ in diameter, and a thin inner membrane closely enveloping the oncosphere, which measures 18 μ in diameter.

DISTRIBUTION.—United States. In Minnesota, this species occurred much less frequently than *Choanotaenia infundibulum,* the only other cestode found in the sharp-tail grouse during the present survey.

Ascaridia galli (Schneider, 1866) Schwartz, 1925

SYNONYMS.—*Heterakis lineata* Schneider, 1866; *Ascaridis hamia* Lane, 1914; *Ascaridia galli (A. perspicillum)* Schwartz, 1925.

HOSTS.—*Anas platyrhyncha domestica, Caccabis saxatilis chukar, Colinus virginianus, Gallus gallus, Meleagris gallopavo, Bonasa umbellus, Pedioecetes phasianellus campestris.*

LOCATION.—Small intestine.

MORPHOLOGY.—Large yellowish worms with 2 very prominent white lateral lines. Head with 3 large subequal lips having 2 dentigerous ridges.

Male.—Fifty-five to 68 mm. long. Anal sucker 200 to 250 μ in diameter, with strong chitinous wall, with a papilliform interruption on its posterior rim. Tail with narrow bursal membranes and 10 pairs of caudal papillae.

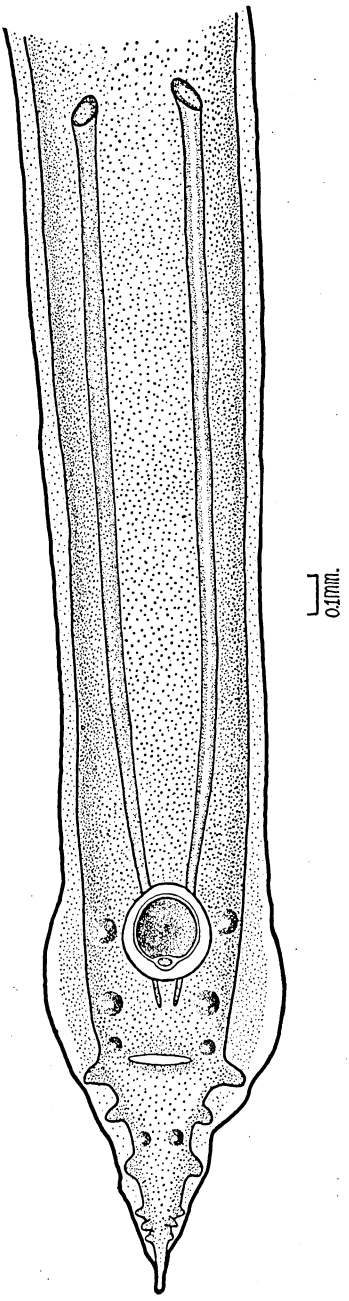


FIG. 6. ASCARIDIA GALLI, MALE TAIL, VENTRAL VIEW

Three pairs of preanal papillae are located ventrally, one pair anterior to the sucker, one pair opposite the sucker, and one pair between the sucker and the cloacal aperture. The next pair may be preanal, adanal or postanal. Close behind this pair is a lateral or ventral pair. This is followed by a ventral pair, and then in turn by a lateral pair. Towards the tail, in the secondary expansion of the caudal alae, are 2 pairs of lateral papillae, with a pair of ventral papillae occupying variable positions between them. Cloacal aperture 540 μ from the tip of the tail. Spicules equal and narrow, with slightly enlarged rounded points, 1.6 to 2.4 mm. long.

Female.—Sixty to 95 mm. long. Vulva at about the union of the anterior and middle thirds of the body length. Tail 1.08 mm. long. Eggs elliptical 80 μ long by 50 μ wide.

LIFE HISTORY.—Development direct.

DISTRIBUTION.—North America (United States), South America (Brazil), Asia, Africa, Europe. In Minnesota *Ascaridia galli* was more common than any other parasite found during the entire period of the survey; 37.42 per cent of the ruffed grouse, and 9.43 per cent of the sharp-tail grouse were infested. This species was common in many of the counties but absent in Polk, Roseau, Cook, and Lake counties.

The specimens examined differed from the above description in the position of the caudal papillae. None were found anterior to the ventral sucker, and 2 pairs occurred between the sucker and the cloacal aperture rather than one pair. Since, however, the 3 posterior pairs are more characteristic of the species, the differences are regarded as variations.

Heterakis gallinae (Gmelin, 1790) Freeborn, 1923

SYNONYMS.—*Ascaris gallinae* Gmelin, 1790; *A. vesicularis* Froelich, 1791, part; *Heterakis vesicularis* (Froelich, 1791) Dujardin, 1845; *H. papillosa* Railliet, 1885, misdet., not *Ascaris papillosa* Bloch, 1782 (equals *Heterakis monticelliana* Stossich, 1892).

HOSTS.—*Anas boschas domestica, A. tadorna, Anser anser, A. cinereus domesticus, Bonasa sylvestris, B. umbellus, Ceriornis satyra, Chenopsis atrata, Chrysolophus pictus, Colinus virginianus virginianus, C. virginianus texanus, Corvus cajanus, Coturnix communis, C. dactytisonans, Cupidonia cupido, Gallus gallus, Grossiptodon manschuricum, Lagopus mutus, Lagopus scoticus, Meleagris gallopavo, Numida meleagris, Ortyx virgianus, Otis tarda, O. tetrax, Pavo cristatus, Pediocetes phasianellus campestris, Perdix cineria, P. coturnix, P. perdix, P. saxatilis, Phasianus colchicus, P. gallus, P. nycthemerus, P. pictus, P. veneratus, P. vesicolor, Tadorna tadorna, Tetrao bonasia, T. lagopus, T. urogallus.*

LOCATION.—Ceca.

MORPHOLOGY.—Mouth with 3 small equal lips, without teeth and each with 2 papillae. Two narrow lateral membranes extend almost the

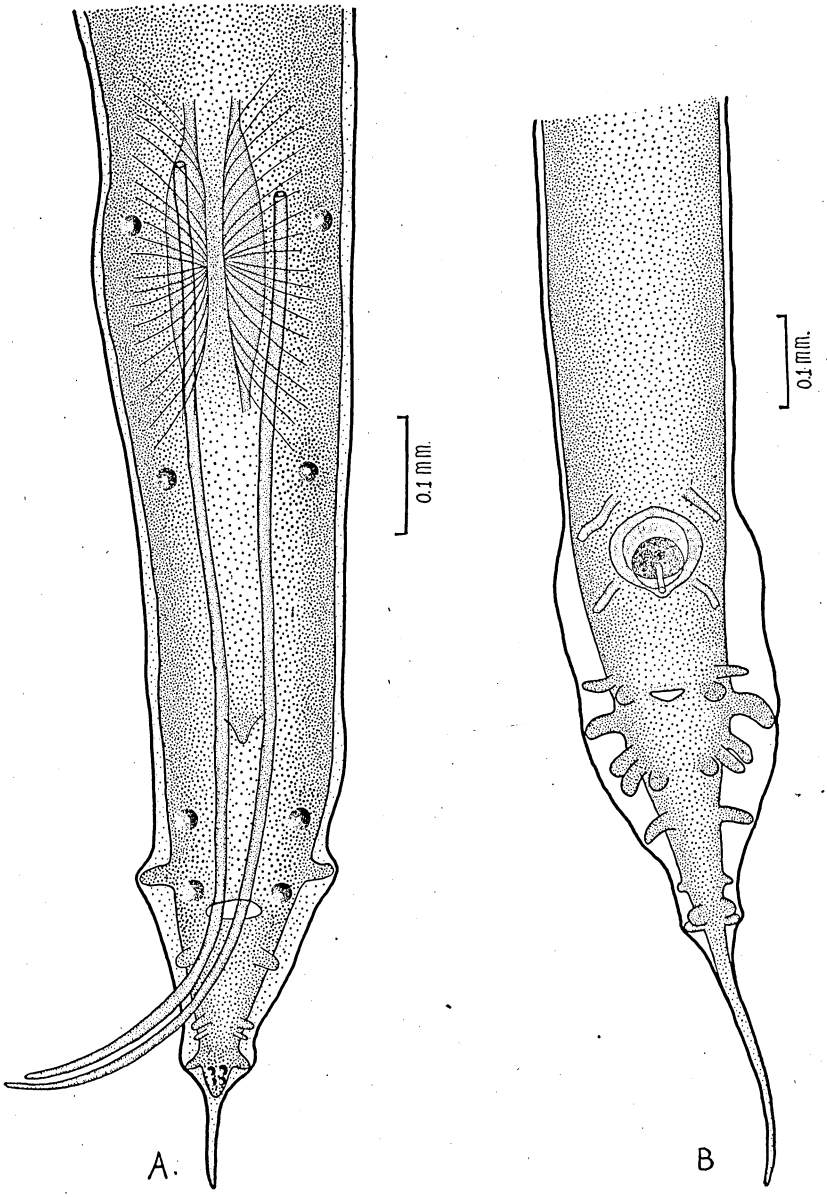


FIG. 7. A. SUBULURA STRONGYLINA, MALE TAIL, VENTRAL VIEW
B. HETERAKIS GALLINAE, MALE TAIL, VENTRAL VIEW

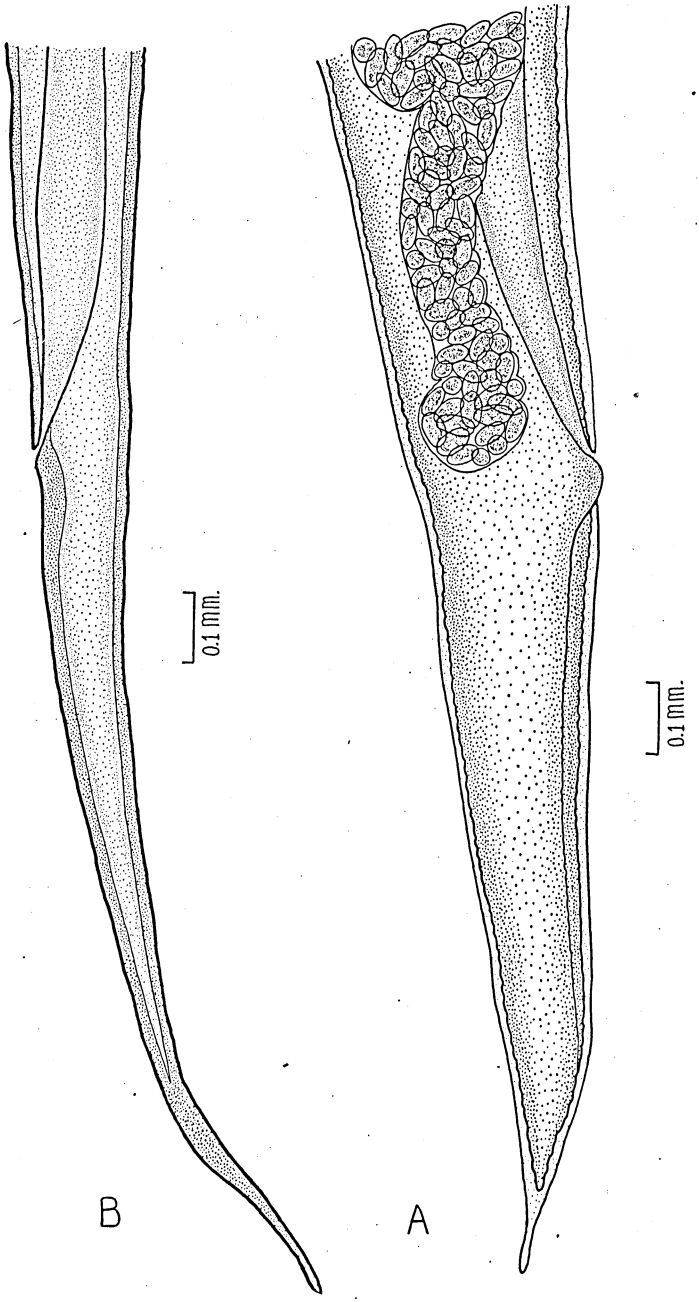


FIG. 8. A. SUBULURA STRONGYLINA, FEMALE TAIL, LATERAL VIEW
B. HETERAKIS GALLINAE, FEMALE TAIL, LATERAL VIEW

entire length of the body. Esophagus with 6 longitudinal rows of transversely placed chitinous rods, and with a well-developed bulb.

Male.—Seven to 13 mm. long. Cloacal aperture 450 μ from the caudal extremity. There are 12 pairs of papillae and a well-developed preanal sucker 60 to 75 μ in diameter; a small semicircular incision occurs in the posterior wall of the sucker. Four pairs of papillae are between the cloacal aperture and the end of the tail, and 2 pairs of ray-like papillae are in the vicinity of the sucker. The spicules are dissimilar, the right being 2 to 2.7 mm. long and the left 700 μ to 1.1 mm. long.

Female.—Ten to 15 mm. long. Tail is pointed, the anus 1.0 mm. or more from the tip. Vulva not salient, situated slightly posterior of the middle of the body. Eggs thick-shelled, ellipsoidal, 63 to 71 μ long by 38 to 48 μ wide.

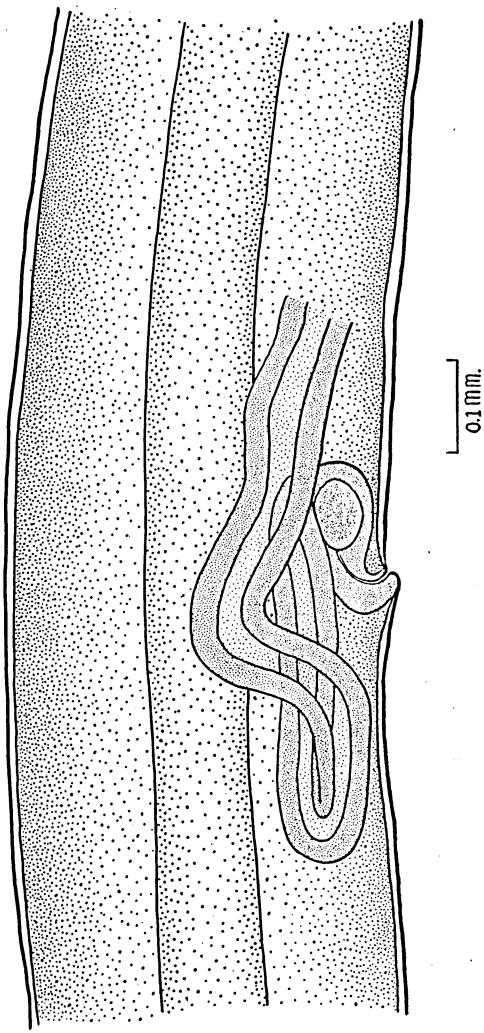


FIG. 9. HETERAKIS GALLINAE, VULVA AND OVEJECTOR

LIFE HISTORY.—Development direct.

DISTRIBUTION.—Cosmopolitan. This species was very rare in Minnesota, only 3 ruffed grouse being infested, comprising a 0.62 per cent infestation.

The morphology of the male of this species differs slightly from that given by Cram (1927) and Clapham (1933). Cram's description states there are 4 pairs of papillae between the cloacal aperture and the end of the tail. The drawing accompanying her description shows that there are either 6 or 7 pairs of papillae between these 2 points. This is the condition found to exist by Clapham (1933) and by the writer in the specimens examined. The length of the shorter spicule also agreed with Clapham's description (650). Cram gives 700 μ as the shortest length

found and uses this length (p. 50, line 16) in her key to the species of *Heterakis*. The key still remains workable if this length is altered. In addition to these discrepancies, neither Clapham nor Cram mention the existence of a distinct papilla within the anal sucker. This papilla appears to arise from the floor of the sucker and lies in the semicircular incision in the posterior margin of the wall of the sucker.

Subulura strongylina (Rudolphi, 1819) Railliet and Henry, 1912

SYNONYMS.—*Ascaris strongylina* Rudolphi, 1819; *Strongylus spiculatus* Cobbold, 1861; *Heterakis spiculatus* (Cobbold, 1861), Travassos, 1923.

HOSTS.—*Bonasa umbellus, Bucco capensis, B. melanoleucos, B. rufiventis, B. striolatus, B. swainsoni, B. tamatina, Caprimulgus ruficollis, C. necandua, C. uratus, Chelidoptera tenebrosa, Colinus virginianus virginianus, C. virginianus texanus, Crypturus noctivagus, C. tatuopa, Cuculus melanorhynchus, C. tinguacu, Gallus gallus, Malocoptila torquata, Microdactylus cristatus, Monasa leucops, M. tranquilla, Nonnula rubecula, Numida meleagris, Odontophorus capueira, Pediocectes phasianellus campestris, Perdix dentata, Podager nacunda, Tetrao ura, Tinamus sp., T. tataupa.*

LOCATION.—Ceca.

MORPHOLOGY.—Lateral alae well developed, 1.37 mm. long by 65 μ wide, extending from the head to the level of the median part of the bulb. Mouth irregular hexagonal, with 6 papillae arranged in 2 lateral series. Buccal capsule 48 μ deep, 3 reticular teeth 19 μ high at the entrance to the esophagus. Bulb spherical 205 μ in diameter.

Male.—Length, 4.36 to 12 mm.; width, 308 μ. Tail conical with straight chitinous appendage 102 μ long. Cloaca 186 μ from the end of the body. Preanal sucker fusiform, without a chitinous ring, 169 μ long, its posterior end being 450 μ from the caudal extremity. Caudal alae rudimentary. Eleven pairs of papillae, of which 3 are preanal, 2 adanal, and 6 postanal. Spicules equal 1.18 mm. long. Gubernaculum 169 μ long.

Female.—Length, 5.6 to 18.7 mm.; width, 411 μ. Tail acute ending in a chitinous appendage 102 μ long. Anus 105 mm. from the posterior end. Vulva very slightly salient, a little anterior to the middle of the body. Ovejector 950 μ long, vestibule sinuous, sphincter small, trompe equivalent to two-thirds the length of the ovejector. Two divergent uteri. Eggs 84 μ long by 67 μ wide.

LIFE HISTORY.—Unknown.

DISTRIBUTION.—North and South America. In Minnesota only one bird, a ruffed grouse, was found infested with this parasite, comprising an infestation of 0.21 per cent.

Only 2 male specimens of this species were found. They differed from Cram's (1927) description in the length of the ventral sucker (280 μ), and the distance of the ventral sucker from the caudal extremity

(620 μ). In addition, a ventral median papilla was found situated between the cloaca and the ventral sucker.

Cheilospirura spinosa Cram, 1927

SYNONYMS.—*Acuaria (Cheilospirura)* species of Stafseth and Kotlan, 1925.

HOSTS.—*Colinus virginianus, Bonasa umbellus, Pedioecetes phasianellus campestris.*

LOCATION.—Gizzard; under the horny lining.

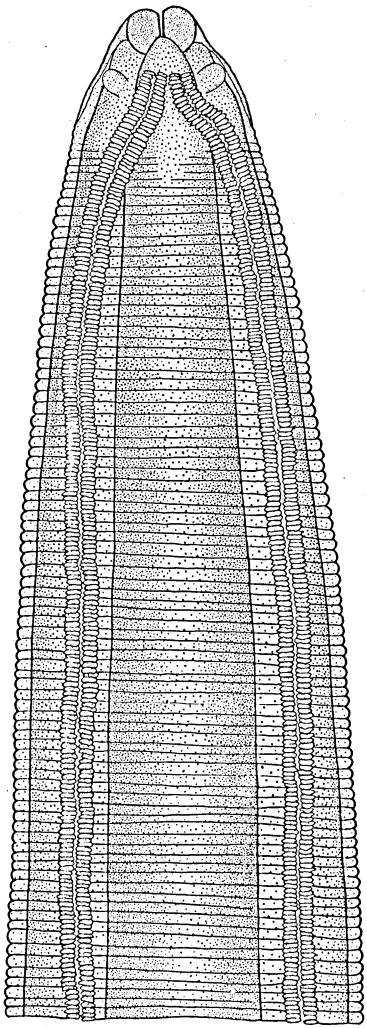


FIG. 10. CHEILOSPIRURA SPINOSA, HEAD REGION OF FEMALE

MORPHOLOGY. — Mouth with 2 triangular lips, at the base of each and projecting slightly beyond its margin is a pair of papillae. Four cordons originating in pairs between the lips; the 2 cordons of each pair gradually swing to the submedian lines and do not extend beyond the anterior third of the anterior esophagus. Cordons double and composed of 2 rows of descrete, sharply pointed elements which project like spines; they may extend for a length of 10/30 to 10/41 of that of the anterior esophagus, the average being 10/35. Cuticle with wide transverse striations. Cervical papillae at the union of the pharynx and esophagus.

Male.—Fifteen mm. long, 183 μ wide at the level of the posterior end of the esophagus, and 232 μ wide in the middle of the body. Cordons 495 μ long. Pharynx or buccal cavity 232 μ long; anterior esophagus 1.1 mm. long, posterior esophagus 2.6 mm. long. Caudal extremity tightly

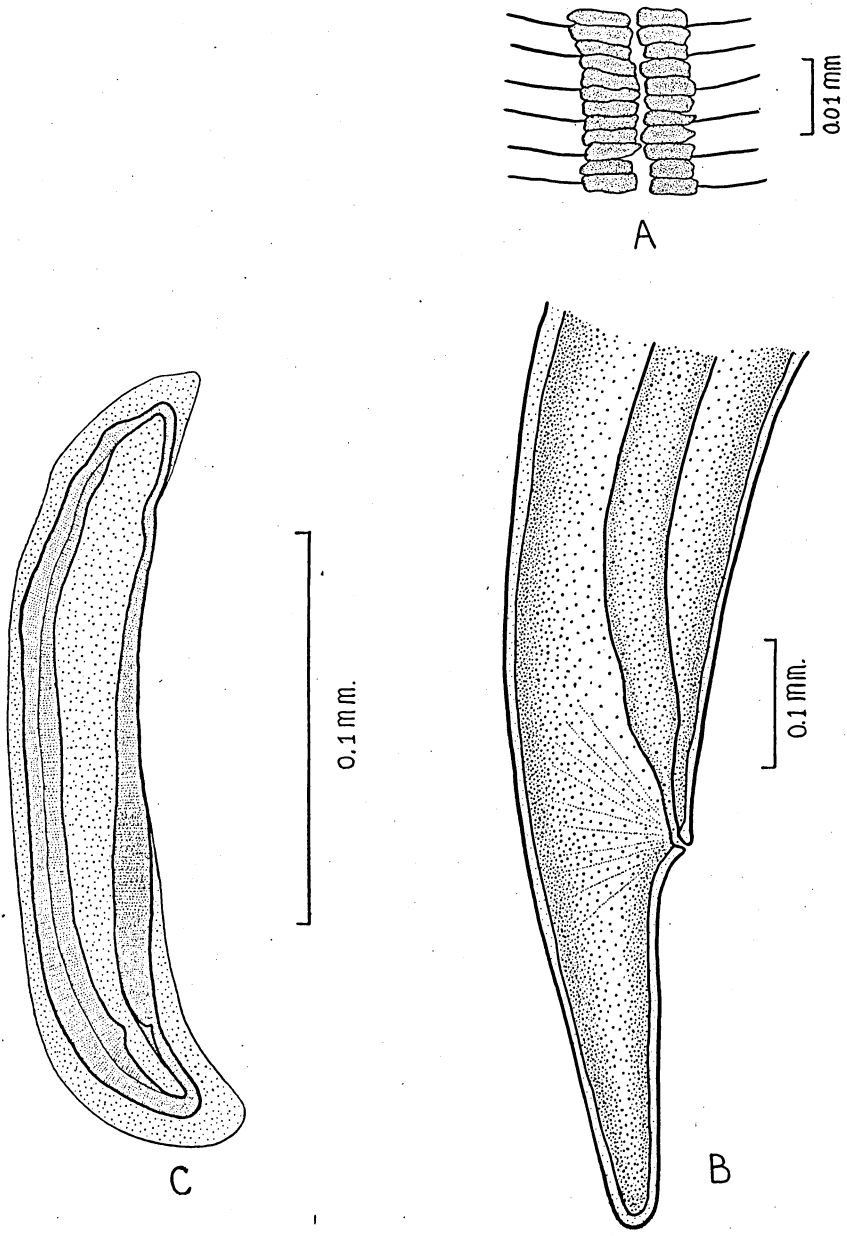


FIG. 11. CHEILOSPIRURA SPINOSA

A. Part of cordon
B. Female tail, lateral view
C. Spicule.

coiled. Caudal alae broad and vesicular, a central band having delicate transverse striations. Caudal papillae very slender; 4 pairs of preanal papillae; 6 pairs of postanal papillae. Cloacal aperture 498 μ from the posterior end of the body. Spicules unequal and very dissimilar, the one slender, 700 to 720 μ long, the other thick, 192 μ long.

Female.—Thirty-four to 38 mm. long by 315 μ wide at the posterior end of the esophagus and 348 μ wide in the middle part of the body. Cordons 797 to ·813 μ long. Pharynx or buccal cavity 232 μ long, anterior esophagus 1.4 mm. long, posterior esophagus 3.4 mm. long. Vulva anterior to the middle of the body dividing the body length in the ratio of 17:23. Anus 250 to 300 μ from the posterior end. Tail slender and digitate. Eggs 39 to 42 μ by 25 to 27 μ.

LIFE HISTORY.—Intermediate hosts are *Melanoplus femur-rubrum, M. differentialis.*

DISTRIBUTION.—United States. In Minnesota this species occurred quite frequently; 18.95 per cent of the ruffed grouse, and 3.39 per cent of the sharp-tail grouse were infested. Altho it is common in many of the counties, it is absent or has a low infestation in Polk, Lake, St. Louis, and Roseau counties.

The specimens examined differed from Cram's (1927) description in the position of the cephalic papillae, and the shape of the cordons. The cephalic papillae do not project beyond its margin, while the cordons are blunt rather than sharply pointed, which is the main point of differentiation between *C. spinosa* and *C. gruveli.* The length of the cordons, size of the spicules, and eggs correspond to those given by Cram for *C. spinosa* and differ from those of *C. gruveli* so that the writer considers the differences are variations of *C. spinosa.*

Seurocyrnea colini (Cram, 1927) Strand, 1929

SYNONYMS.—*Cyrnea colini* Cram, 1927.

HOSTS.—*Colinus virginianus virginianus, C. vir. texanus, Meleagris gallopavo, Tympanuchus americanus americanus, Pedioecetes phasianellus campestris.*

LOCATION.—Wall of the proventriculus, at its junction with the gizzard.

MORPHOLOGY.—Head with 4 lips, dorsal and ventral lips prominent, deeply divided into 2 parts in such a manner that in lateral view, the head appears to bear 4 conspicuous projecting papillae. Each papilla bears on its outer edge a prominent thumblike extension. Lateral lips very large, each bearing 2 digitiform processes on its inner surface, and 2 lateral winglike expansions which project into the median groove of the dorsal and ventral lips in such a manner as to give the appearance in some views of being processes from the lateral lips. Two obscure lateral papillae occur near the base of the lateral lips.

Male.—Six mm. long by 250 μ wide. Buccal cavity 58 μ deep, total length of the esophagus 2 mm. Caudal alae outspread, 280 μ long, their

span 230 μ, bearing transverse striations. Cloacal aperture about 115 μ from the posterior end. Ten pairs of pedunculated papillae forming an unbroken series, the 4 most posterior pairs slightly smaller than the others, the seventh pair from the posterior end opposite the cloacal aperture. Left spicule 2 mm. long by 12 μ wide, right spicule 365 μ long by 24 μ wide. Gorgeret delicate, the left side (68 μ in length) is longer than the right.

Female.—Fourteen to 18 mm. long by 365 μ wide. Buccal cavity 75 μ deep; first part of the esophagus about 280 μ long, second part of the esophagus about 2.5 mm. long. Tail 332 μ long. Vulva only slightly salient, 915 μ anterior to the anus. Vestibule including sphincter 1.2 mm. long. Eggs 40.5 μ by 22.5 μ.

LIFE HISTORY.—Secondary hosts. Cram (1933) found that cysts developed in *Melanoplus femur-rubrum,* and in nymphs of *Chortophaga viridifasciata* and *Blatella germanica,* but attempts to infest turkeys, pigeons, and chickens were unsuccessful.

DISTRIBUTION.—United States. This species of parasite was not found in Minnesota, but 2 out of 6 sharp-tail grouse from South Dakota were infested.

Oxyspirura mansoni (Cobbold, 1879) Ransom, 1904

SYNONYMS.—*Filaria mansoni* Cobbold, 1879; *Spiroptera emmerezii* Emmerez and Megnin, 1901; *Spiroptera mansoni* (Cobbold, 1879) Gedoelst, 1903.

HOSTS.—*Bonasa umbellus, Gallus gallus, Meleagris gallopavo, Pavo cristatus.*

LOCATION.—Under the nictating membrane, and occasionally in the nasal cavities and sinuses.

MORPHOLOGY.—Body attenuated at both ends, the anterior end rounded, the posterior end pointed. Cuticula smooth. A pair of small papillae near the tip of the tail in both sexes. Mouth circular, surrounded by a 6-lobed chitinous ring, and with 2 lateral and 4 submedian papillae in relation with the clefts of the ring; 4 sublateral papillae posterior to these. A pair of cervical papillae near the origin of the esophagus which is about 1.5 mm. long.

Male.—Ten to 16 mm. long by 350 μ wide. Cloacal aperture 320 to 400 μ from the tip of the tail. Four pairs of preanal and 2 pairs of postanal papillae. Spicules unequal, one is 3 to 3.5 mm. long by 8 to 10 μ wide, the other is 220 μ long by 30 μ wide.

Female.—Twelve to 19 mm. long by 430 μ wide. Anus 400 to 530 μ from the tip of the tail. Vagina 1.5 to 2 mm. long. Eggs oval 50 to 65 μ by 45 μ. Larva, first stage, 225 to 250 μ long by 12 μ wide. Esophagus 50 μ long. Head end rounded. Tail end terminates in a thick, blunt appendix.

LIFE HISTORY.—Secondary hosts. The only intermediate host found reported for this species is the cockroach *Pycnoscelus surinamensis.*

Fielding (1928) reports this cockroach as the intermediate host in Australia for *Oxyspirura parvovum,* which Baylis (1934) regards as a synonym of *O. mansoni.* Sanders (1929) reported the cockroach as the intermediate host in Florida in this country. *Pycnoscelus surinamensis* is not reported for Minnesota. It is a subtropical form mainly, but has been reported as occurring in greenhouses as far north as the New England States.

DISTRIBUTION.—North America, South America, Australia, Asia, Africa, Islands of Guam, Hawaii, Jamaica, Danish West Indies, Island of Maurice, Dutch Indies, and Samoa. In Minnesota only 3 ruffed grouse were infested with this parasite, comprising an infestation of 2.12 per cent.

Only 3 specimens of this species were recovered from 3 birds. They were all females, and 2 of them were badly decomposed and impossible to identify. The one specimen identified followed the above description very closely, with the exception of the size of the eggs, which measured an average of 36 to 39 μ long by 25 μ wide. The egg measurements, however, were made from eggs containing embryos located in the uterus. The egg measurements do compare favorably with measurements given by Smit (Cram 1927) for a species from the Dutch Indies which he identified as *O. mansoni.*

Physaloptera sp. larva. Rudolphi, 1819

Larval nematodes 2 to 3 mm. long were found encysted near the surface of the muscles of the breast and in the muscles of the legs. The cysts themselves usually were yellowish in color, measuring about 2 mm. long. The number found in an individual varied from one to many dozens. Cram (1931c) has identified the larva as belonging to the general group of spirurids, and possibly representing a species of Physaloptera, but points out that the location in the surface muscles is unusual, as aberrant spirurids usually encyst in or near the walls of the digestive tract.

HOSTS.—Primary, unknown; secondary, *Bonasa umbellus.*

DISTRIBUTION.—United States (Minnesota and Wisconsin). In Minnesota this parasite was found in only 16 ruffed grouse, comprising an infestation of 3.25 per cent. The central eastern part of the state was the main center of infection.

Agamodistomum sp.

Encysted adolescaria were found in the subcutaneous tissue of the breast or imbedded in the breast muscles. Occasionally cysts were found on the outer surface of the crop. The cysts had a white pearly appearance and measured about 0.5 mm. In many cases where they were encysted in the muscles, they were very difficult to see and might easily be overlooked. These larval trematodes have been identified by Mr. G.

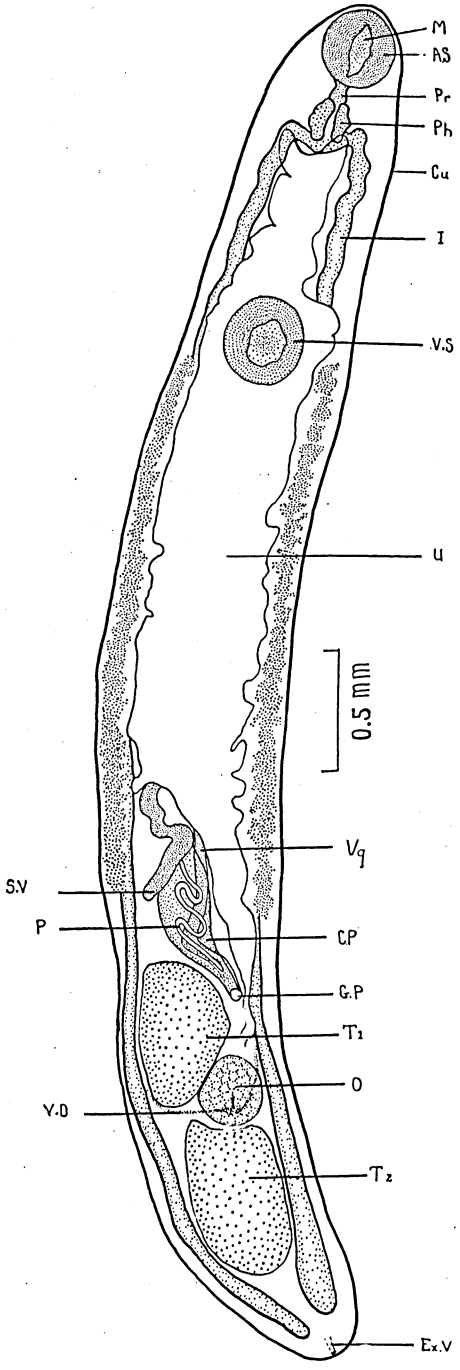


FIG. 12. HARMOSTOMUM PELLUCIDUM, VENTRAL VIEW

A. S. Anterior sucker
C. P. Cirrus pouch
Cu. Cuticle
Ex. V. Excretory vesicle
G. P. Genital pore
I. Intestine
M. Mouth
O. Ovary
P. Penis
Ph. Pharynx
Pr. Prepharynx
S. V. Seminal vesicle
T_1. Anterior testis
T_2. Posterior testis
U. Uterus
Vg. Vagina
V. S. Ventral sucker
V. D. Vas defferens

Fredine of the Department of Entomology, University of Minnesota, as belonging to the family Strigeidae.

HOSTS.—*Bonasa umbellus, Pedioecetes phasianellus campestris.*

DISTRIBUTION.—United States (Minnesota, Michigan, and Wisconsin). In Minnesota, 80 ruffed grouse, or 16.26 per cent of the birds examined, and one sharp-tail grouse, or 1.88 per cent of the birds examined, were infested. Two centers of infection appear to occur, namely, Roseau and Crow Wing counties.

Harmostomum (Harmostomum) pellucidum Werby, 1928

HOSTS.—*Planesticus migratorius propinquus, Bonasa umbellus.*

LOCATION.—Ceca.

MORPHOLOGY.—Body cylindrical or slightly flattened, with the ends about the same size and rounded. Length 1.22 to 2.88 mm. by 0.55 to 0.564 mm. wide. Very small blunt spines cover the lateral edges of the body, extending posteriorly as far as the level of the testes. Anterior sucker, slightly oval in shape, 155 μ to 200 μ by 136 μ to 182 μ in size, its ventral opening long and slit-like, measuring 18 to 100 μ wide. Ventral sucker 136 to 209 μ by 209 μ, almost spherical with a circular opening. It lies about one-third of the body length posterior to the anterior sucker, except in the undeveloped form, where it lies in the middle of the body. Digestive tract consists of a short pear-shaped prepharynx, globular pharynx 62 to 91 μ by 19 to 82 μ, a short esophagus, and the intestinal diverticula. The crura of the intestine pass first to the side and anteriorly, then make a right-angled turn posteriorly and pass to the posterior end of the body, ending blindly. The ceca pursue a tortuous course posteriorly to the ending.

The reproductive systems occupy the entire space between the intestinal branches, from a point anterior to the ventral sucker, to a point slightly anterior to the terminations of the intestinal ceca. Occupying the posterior portion of this space are the glands, the testes lying tandem with the ovary between them. The anterior testis measures 136 to 273 μ by 173 to 291 μ. The posterior testis measures 127 to 273 μ by 136 to 255 μ. Each vas efferens comes off from the left side of its respective testis and runs alongside the anterior testis, where the single duct enters the coiled saccular seminal vesicle. Lying free in the parenchyma, the prostate gland surrounds that part of the ejaculatory duct which connects the seminal vesicle and the cirrus pouch. The cirrus pouch contains the straight ejaculatory duct and the coiled penis. The ovary measures 91 to 173 μ by 109 to 182 μ. There is no seminal receptacle. Laurer's canal originates in that portion of the uterus just following the oötype, which gives rise to the slender uterus. The vagina approaches the genital pore from the left. Extending anteriorly from the genital pore, the cirrus pouch is pear-shaped, the wider portion emptying through the pore, which lies on the right lateral border of the anterior testis. Clearly defined as follicular glands, the vitelline glands lie to the outside of the

intestinal ceca and extend from the level of the middle of the ventral sucker to the level of the middle of the anterior testis. Eggs are concave-convex and measure 22.8 to 28 by 18 μ.

LIFE HISTORY.—Unknown.

DISTRIBUTION.—United States. In Minnesota the species was confined to the ruffed grouse, 10 birds, or 2.08 per cent of the birds examined were infested. Roseau County appears to be the main center of infection.

While many of the specimens measured fell within the limits given by Werby (1928), a number were considerably larger. Table 1 shows a comparison between the principal measurements obtained from the specimen on hand and those given by Werby. By dividing the measurements obtained from this largest specimen by 2, the resulting measurements all fell within the limits given by Werby, with the exception of the total length, length and width of the pharynx, and the length of the posterior testis. Since the majority of the measurements are practically in the direct proportion to those given by Werby, it is safe to assume them to be the same species. It is merely another case illustrating the limits to which measurements can be used in the separating of species.

Table 1. Comparison of Measurements of Largest Specimen of Harmostomum pellucidum Examined, with Werby's Measurements

Structure	Werby's measurements in μ	Measurements of largest specimen in μ	Divided by 2
Length	1,228-2,885	6,300	3,150
Width	255-564	764	382
Length anterior sucker	155-200	340	170
Width anterior sucker	136-182	340	170
Length of slit in anterior sucker	73-118	220	110
Width of slit in anterior sucker	18-100	84	42
Length of ventral sucker	146-209	356	178
Width of ventral sucker	136-209	322	161
Length of pharynx	62- 91	204	102
Width of pharynx	19- 82	186	93
Length anterior testis	173-291	576	288
Width anterior testis	136-273	442	221
Length of posterior testis	136-255	680	340
Width of posterior testis	127-273	408	204
Length of ovary	109-182	322	161
Width of ovary	91-173	254	127
Eggs	22.8-28x18	28-33x18	.....

Eimeria dispersa Tyzzer, 1929

HOSTS.—*Colinus virginianus, Bonasa umbellus, Gallus domesticus, Meleagris mexacana, Phasianus colchicus, Pediocectes phasianellus campestris.*

LOCATION.—Small intestine.

MORPHOLOGY.—*Eimeria dispersa* is differentiated from any other species of coccidia in gallinaceous birds by the absence of any well-

defined polar inclusions in the oöcyst. The oöcysts of *E. dispersa* are ovoidal in shape, the average dimensions being 22.75 μ by 18.84 μ. The shells of the oöcysts are quite delicate.

DISTRIBUTION.—United States. In Minnesota 24 ruffed grouse, or 6.46 per cent, and 1 sharp-tail, or 3.33 per cent of the birds examined, were infested.

The oöcysts of this species, examined by the writer, possessed a light grayish to light metallic shell, the protoplasm within having a fine granular structure. The maximum and minimum measurements obtained were 22.8 by 20.4 μ, and 18.0 by 16.8 μ.

Eimeria angusta Allen, 1934

HOSTS.—*Bonasa umbellus, Canachitis canadensis, Pediocetes phasianellus campestris.*

LOCATION.—Ceca.

MORPHOLOGY.—Oöcysts 16.5 to 17.5 μ by 27 to 33 μ. Operculum in a non-refractile layer outside the layer of the oöcyst wall, not always readily seen. A thin membrane lining the oöcyst wall and inclosing the 4 sporonts and a very small residual body.

DISTRIBUTION.—Labrador, Alaska, United States (Minnesota). In Minnesota 4 ruffed grouse, or 1.08 per cent, and 1 sharp-tail, or 2.56 per cent of the birds examined, were infested.

The oöcysts examined by the writer averaged 16.10 by 30.07 μ. The maximum length and width obtained were 32.98 and 16.88 μ, respectively; the minimum length and width obtained being 27.16 and 14.5 μ, respectively.

COMPARISON OF INFESTATIONS

The results of the entire survey covering Minnesota, Michigan, Wisconsin, and South Dakota are summed up in Tables 2 and 3. Of the 560 ruffed grouse examined, 15 were caught in the summer of 1933-34 and will be discussed elsewhere in this bulletin. Infestation by *Eimeria* has not been included in the general data but will also be discussed later.

A casual examination of Tables 2 and 3 will show there are striking differences between the degrees of infestation in the two species of grouse examined. The total infestation and the infestation by the different species concerned are lower in the sharp-tail grouse than in the ruffed grouse, with the exception of the cestodes. The principal helminths of the ruffed grouse, *Ascaridia galli* and *Cheilospirura spinosa,* would seem to be rare in the sharp-tail grouse. In the course of this study, *Oxyspirura mansoni* and *Harmostomum pellucidum* have been found only in the ruffed grouse and *Seurocyrnea colini* only in the sharp-tail grouse. The *Physaloptera* larva and the *Agamodistomum sp.* in the sharp-tail, and *Subulura strongylina* and *Heterakis gallinae* in the ruffed grouse may even be considered as accidental parasites.

Table 2. Relative Frequency of the Parasites of Ruffed Grouse

Parasite	Per cent infested	Number infested / Number examined	Average number	Maximum number
Ascaridia galli	37.26	199/533	6.1	64
Cheilospirura spinosa	23.11	122/527	3.8	30
Heterakis gallinae	.56	3/533	1.7	3
Oxyspirura mansoni	2.58	4/155	1	1
Subulura strongylina	.18	1/533	12	12
Harmostomum pellucidum	2.44	12/533	5.2	18
Cestodes	4.11	23/533	?	?
Physaloptera larva	4.04	22/544	12.5	61
Agamodistomum sp.	15.81	86/544	10.5	102
Total infestation	56.84	310/545	.....	.....

Table 3. Relative Frequency of Parasites of the Sharp-tail Grouse

Parasite	Per cent infested	Number infested / Number examined	Average number	Maximum number
Ascaridia galli	8.06	5/62	2.4	6
Cheilospirura spinosa	4.84	3/62	1.8	4
Heterakis gallinae	1.61	1/62	1	1
Subulura strongylina	4.84	3/62	1.6	2
Seurocyrnea colini	3.22	2/62	3.5	4
Cestodes	24.19	15/62	?	?
Physaloptera larva	1.61	1/62	5	5
Agamodistomum sp.	1.61	1/62	7	7
Total infestation	40.32	25/62	.....	.....

The relative frequency of the helminths is given for Minnesota alone in Tables 4 and 5. These tables also show a comparison of the frequency of the parasites during the four separate periods of the survey. With regard to the relative frequency of the parasites during the total period of the survey, a comparison of the two tables shows the same differences in infestation that have already been pointed out in the comparison of Tables 2 and 3, but a comparison of Tables 3 and 5 shows the absence of *Subulura, Heterakis,* and *Seurocyrnea* in any of the 53 sharp-tail grouse from Minnesota. This is all the more remarkable since these three species were recovered from an examination of only six birds from South Dakota and indicates, possibly, a scattered distribution of the parasites. Sufficient numbers of sharp-tail grouse were not examined, during different periods of the survey, to enable an accurate analysis of the infestation to be made. In the case of the ruffed grouse, however, which is the chief object of study, an examination of Table 4 shows some very striking differences in the degree of infestation. In the first place, there is a remarkable increase in the total percentage of infestation from 36.54 per cent in 1931-32 to 73.79 per cent in 1933-34. This increase in infestation also follows roughly for the individual species of helminths concerned. In 1934-35, however, Table 4 shows a consider-

able drop, not only in the case of the total infestation, but also in the infestation by the individual species. *This decrease in the percentage of infestation in 1934-35 is due primarily to a "parasitic distribution" in the state, and because of this the writer believes that Table 4 does not show the true conditions that have existed during the different periods of the survey.* Parasitic distribution implies that there are distinct differences in the percentages of infestations in birds from different parts of the state. This condition will be discussed in detail later.

In comparing the infestation of the ruffed grouse in the different states, adequate numbers of birds on which a comparison could be made were examined only during 1933-34. Comparison of the infestation in Michigan, Wisconsin, and Minnesota is shown in Table 6. According to these figures, the degree of parasitism in the three states varies considerably; 88.23 per cent infestation in specimens received from Wisconsin is remarkably higher and 45.45 per cent in specimens from Michigan is considerably lower than the infestation of 73.79 per cent from specimens in Minnesota. This difference in the degree of infestation in Wisconsin and Michigan is in all probability due to a parasitic distribution, similar to that which occurs in Minnesota.

In comparing the infestation of the 23 counties in Minnesota, a number of differences can be noticed in the degree of infestation in different areas. These differences are:

1. In the case of *Ascaridia galli,* a large percentage of the birds are infested from such counties as Pine, Cass, and Carlton, while no such infestation has been found in birds from Polk, Roseau, Cook, and Lake counties.

2. Two main centers of infection appear to occur in the case of *Agamodistomum sp.,* namely Roseau and Crow Wing counties.

3. *Cheilospirura spinosa* is "common" in many of the counties, but is absent or has a low infestation in Polk, Lake, St. Louis, and Roseau counties.

4. In general, there has been an increase in parasitism in the separate counties under consideration, not only in the total infestation, but also in the cases of the individual species of parasites during the four periods of the survey.

5. Some counties, in general, show a high infestation, both in species and in total infestation, while others show a low infestation in species and total infestation.

The differences indicated above are of sufficient magnitude to indicate clearly that a "parasitic distribution" occurs in the state.

The area covered by the survey has been divided into three arbitrary zones, each of which the writer believes shows a clear-cut difference in the frequency of the parasites involved. Zone 1 lies in the northeast corner of the state (Map 1); Zone 2 lies in the northwest corner of the state, and Zone 3 lies in the middle east section of the state.

Table 4. Comparison of Infestation in Ruffed Grouse in Minnesota During Four Periods of the Survey

Parasite	1931-32, per cent	No. infested / No. examined	1932-33, per cent	No. infested / No. examined	1933-34, per cent	No. infested / No. examined	1934-35, per cent	No. infested / No. examined	Total 1931-35, per cent	No. infested / No. examined
Ascaridia galli	30.76	16/52	27.93	50/179	50.00	72/144	39.62	42/106	37.42	180/431
Cheilospirura spinosa	3.84	2/52	8.08	16/173	25.00	36/144	33.99	36/106	18.95	90/475
Heterakis gallinae	0.0	0/52	0.0	0/179	1.46	2/144	.94	1/106	.62	3/481
Oxyspirura mansoni			0.0	0/21	0.0	0/28	2.83	3/106	2.12	3/142
Subulura strongylina	0.0	0/52	.56	1/179	0.0	0/144	0.0	0/106	.21	1/481
Harmostomum pellucidum	0.0	0/52	1.67	3/179	4.17	6/144	.94	1/106	2.08	10/481
Cestodes	5.76	3/52	1.12	2/179	5.55	8/144	3.77	4/106	2.49	10/481
Physaloptera larva	0.0	0/52	4.23	8/189	4.13	6/145	1.88	2/106	3.25	16/492
Agamodistomum sp.	0.0	0/52	19.04	36/189	23.44	34/145	9.43	10/106	16.26	80/492
Total infestation	36.54	19/52	46.37	88/190	73.79	107/145	59.43	63/106	55.81	275/493

Table 5. Comparison of Infestation in Sharp-tail Grouse of Minnesota During Three Periods of the Survey

Parasites	1931-32, per cent	No. infested / No. examined	1932-33, per cent	No. infested / No. examined	1933-34, per cent	No. infested / No. examined	Total, 1931-34, per cent	No. infested / No. examined
Ascaridia galli	9.52	2/21	8.33	1/12	10.00	2/20	9.43	5/53
Cheilospirura spinosa	4.76	1/21	0.0	0/12	5.00	1/20	3.39	2/53
Cestodes	23.80	5/21	33.33	4/12	25.00	5/20	26.41	14/53
Agamodistomum sp.	0.0	0/21	8.33	1/12	0.0	0/20	1.88	1/53
Total infestation	38.09	8/21	41.66	5/12	30.00	6/20	41.32	22/53

Table 6. Comparison of State Infestation of Ruffed Grouse in 1933-34

Parasites	Per cent infested, Minnesota	No. infested / No. examined	Per cent infested, Michigan	No. infested / No. examined	Per cent infested, Wisconsin	No. infested / No. examined
Ascaridia galli	50.00	72/144	31.81	7/22	70.58	12/17
Cheilospirura spinosa	25.00	36/144	18.18	4/22	29.58	5/17
Heterakis gallinae	1.46	2/144	0.0	0/22	0.0	0/17
Harmostomum pellucidum	4.17	6/144	4.54	1/22	0.0	0/17
Cestodes	5.55	8/144	0.0	0/22	23.52	4/17
Physaloptera larva	4.13	6/145	0.0	0/22	5.88	1/17
Agamodistomum sp.	23.44	34/145	13.63	3/22	11.17	2/17
Total infestation	73.79	107/145	45.45	10/22	88.23	15/17

The differences in infestation, indicated in an examination of the county infestation, can now be emphasized more by comparing the infestation in the different zones outlined. Table 7 shows a comparison of the total infestation in the three zones for the entire period of the survey and a comparison of the total infestation in the three zones for each period of the survey.

A careful examination of this table shows:

1. The total infestation for the entire period of the survey is over 15 per cent higher in Zone 3 than in Zone 2 and over 20 per cent higher in Zone 2 than in Zone 1.

2. The total infestation for each period of the survey, except in one case, is higher in Zone 3 than in Zone 2 and higher in Zone 2 than in Zone 1.

3. In any one zone, except in two cases (see Table 7), there has been an increase in parasitism in each succeeding period of the survey.

Table 7. Comparison of Total Infestation in Ruffed Grouse from Different Zones

Year	Per cent infested, Zone I	No. infested / No. examined	Per cent infested, Zone II	No. infested / No. examined	Per cent infested, Zone III	No. infested / No. examined
1931-32	19.18	2/11	66.66*	6/9	34.37	11/32
1932-33	26.83	11/41	34.36	11/32	58.12	66/117
1933-34	56.47	13/23	59.09	13/22	81.00	81/100
1934-35	14.81*	4/27	59.09	13/22	81.81	45/55
Total infestation	28.71	29/101	50.59	43/85	66.78	203/304

* See Section 3 above the table.

4. A definite "parasitic distribution" does occur in the state.

5. *Table 7 represents the actual increase in parasitism rather than Table 4, and the drop in the percentage of infestation between 1933-34 and 1934-35 indicated in Table 4 is mainly because more birds were received from Zones 1 and 2 (in which infestation is relatively low) during 1934-35 than in any other period of the survey,* and because of an exceptionally low infestation in Zone 1. In 1934-35, 47.11 per cent of the birds were from Zones 1 and 2; in 1933-34, 31.03 per cent of the birds were from Zones 1 and 2; in 1932-33, 38.42 per cent of the birds were from Zones 1 and 2; in 1931-32, 34.37 per cent of the birds were from Zones 1 and 2.

6. In Zones 2 and 3 infestation was equal or slightly higher in 1934-35 than in 1933-34. In Zone 1, on the other hand, it was considerably lower. With such a low infestation in Zone 1, the possibility of getting a representative sample of birds from that area is considerably less than in the other two zones, and since the infestation in the other two zones has remained practically stationary between 1933-34 and 1934-35, the writer considers the low infestation of 14.81 per cent in Zone 1 for 1934-35 an accident. The same applies to the high infestation of 66.66 per cent in Zone 2 for 1931-32.

Tables 8, 9, and 10 show a comparison of the infestation of the three most common parasites found during the survey, namely, *Ascaridia galli, Cheilospirura spinosa,* and *Agamodistomum sp.* Altho as might be expected, there are many more discrepancies in the data given here than there are in Table 7, the same conditions apply to the individual species as to the total infestation. Some of the discrepancies that do occur will be explained later when the factors determining the parasitic distribution are discussed.

Table 8. Comparison of Infestation in Ruffed Grouse with Ascaridia galli from Different Zones

Year	Per cent infested, Zone I	No. infested / No. examined	Per cent infested, Zone II	No. infested / No. examined	Per cent infested, Zone III	No. infested / No. examined
1931-32	18.18	2/11	44.44	4/9	31.25	10/32
1932-33	12.19	5/41	9.67	3/31	39.25	42/107
1933-34	47.82	11/23	0.0	0/22	61.61	61/99
1934-35	11.11	3/27	27.27	6/22	60.00	33/55
Total infestation	20.59	21/102	15.59	13/84	49.82	146/293

Table 9. Comparison of Infestation with Cheilospirura spinosa in Ruffed Grouse from Different Zones

Year	Per cent infested, Zone I	No. infested / No. examined	Per cent infested, Zone II	No. infested / No. examined	Per cent infested, Zone III	No. infested / No. examined
1931-32	0.0	0/11	22.22	2/9	0.0	0/32
1932-33	2.44	1/41	6.45	2/31	11.88	12/101
1933-34	13.43	3/23	4.54	1/22	32.32	32/99
1934-35	0.0	0/27	22.73	5/22	56.36	31/55
Total infestation	3.92	4/102	11.90	10/84	26.13	75/287

Table 10. Comparison of Infestation with Agamodistomum sp. in Ruffed Grouse from Different Zones

Year	Per cent infested, Zone I	No. infested / No. examined	Per cent infested, Zone II	No. infested / No. examined	Per cent infested, Zone III	No. infested / No. examined
1931-32	0 0	0/11	0.0	0/9	0.0	0/32
1932-33	17.5	7/40	6.25	2/32	22.22	26/117
1933-34	13.04	3/23	18.18	4/22	27.00	27/100
1934-35	0.0	0/27	31.82	7/22	5.45	3/55
Total infestation	9.90	10/101	15.27	13/85	18.42	56/304

The question naturally arises as to whether the seasonal variation has influenced any of the results presented in the foregoing tables. If any seasonal variation does occur, one would expect it to be higher during September to December rather than during January to April, because

it is only natural that many of the parasites would be lost during the winter months. In general, the temperature during January to April would not only inhibit any egg development taking place outside of the host, but it would also prevent practically all activity in the case of the intermediate host, if any occurs. Because there is a parasitic distribution, it is quite evident that the monthly infestation would not show a seasonal variation but would be more indicative of the infestation in the particular zone from which the birds were received. The only method of determining whether a seasonal fluctuation occurs is by comparing the infestation within the same zone. Practically all the birds in 1931-32 and 1934-35 were examined in the fall, and therefore a comparison between fall and spring infestation is only possible during 1932-33 and 1933-34, and even during these two periods an average cannot be determined in Zones 1 and 2. In Zone 3 a comparison between fall and spring infestation can be made by taking the average total infestation from September to December, inclusive, and comparing it with the total infestation from January to April, inclusive. Practically all the birds examined were received during these eight months. In 1932-33 during the "fall" months 73 birds were examined, of which 37 were infested, giving a total infestation of 50.68 per cent. During the "spring" months of the same period 29 out of 44 birds were infested, giving a total infestation of 65.91 per cent. In 1933-34 during the "fall" months 35 out of 45 birds were infested, giving a total infestation of 77.77 per cent, and during the "spring" months 46 out of 55 birds were infested, giving a total infestation of 83.36 per cent. These results indicate an actual increase in the total infestation during the "spring" months, so that one may conclude that there is practically no loss of parasites during the eight months' period September to April.

Infestation by *Eimeria* has apparently been very spasmodic during the four periods of the survey. During the periods 1931-32 and 1932-33, examinations for coccidia were made by Dr. F. Wallace. During 1931-32, three out of 52 (3.84 per cent) birds examined were infested. During 1932-33, two out of 179 (1.11 per cent) birds examined were infested. In 1933-34 the writer examined 63 birds, all of which were negative. In 1934-35, of the 77 birds examined 23 (29.87 per cent) were infested. All of the cases were of a mild type. As a check, sections of the digestive tract from 75 of the 77 birds examined were made, but in no case could the presence of the parasite be detected.

During June 1934, 14 young ruffed grouse, ranging in age from a few hours to 10 days, and one adult bird were examined. The adult was infested with *Ascaridia galli* and *Cheilospirura spinosa*. Eight of the young birds ranged in age from six hours to seven days and all were negative. Five of the birds were infested with *Raillietina tetragona*. Two scolices of this cestode were found in a bird four days old. The maximum number of cestodes found in any one bird was 23. In the 10-day-old birds the cestodes were mature and identification was possible. One

immature specimen of *Ascaridia galli* was found in a bird eight days old. Faecal examinations and sections gave negative results in an examination for species of *Eimeria.*

PATHOGENICITY OF THE PARASITES

During the present survey, none of the parasites appeared to produce pathological conditions which materially affected the health of the bird. In fact, with the exception of a few undersized specimens, the grouse were remarkably healthy. Pathological conditions may have been produced by some of the parasites, but they were not recognized.

However, among the parasites found, there is no doubt that some are potentially dangerous. Cram (1930a) reported that *Cheilospirura spinosa* is capable of causing death in ruffed grouse. In a few of the infested specimens examined the lining of the gizzard appeared to be weakened considerably, but the tissue did not appear necrotic or hemorrhagic. The number of worms found in any one individual never exceeded 30, the average being 3.8.

Pathological effects produced by *Ascaridia galli* have not been demonstrated in the grouse. Birds harboring a maximum of 64 specimens appeared in a perfectly healthy condition. According to Ackert (1924), this parasite in poultry may cause hemorrhages during the period it invades the intestinal wall. Cram (1930b) stated that in infestations of this parasite, the appetites of the chicks are reduced in the early stages and that if the chicks survive they later become voracious. Immature worms bury their heads deeply in the intestinal wall, with the resultant destruction of the intestinal glands from the tenth to the seventeenth day after infection is acquired. Since immature forms of this parasite were found in a young grouse only eight days old, it may produce considerable pathological effects in young birds. The number of worms found in any adult never exceeded 64, the average being 6.1.

No pathological conditions were observed with regard to either the encysted nematode and trematode in the subcutaneous tissue and muscles. What effect these larval forms produce while migrating through the host tissue is not known. The maximum number of trematode cysts found in any individual was 102, the average being 10.5. In the case of the nematode, the maximum number was 61 and the average 8.

Among the cestodes, the important species found was *Raillietina tetragona.* This worm was found in young chicks as early as the fourth day. In one case 23 scolices were found, many of which were buried in the intestinal mucosa. The writer regards this species as one of the two most important parasites found during the survey, due to the serious effects which it produces in young quail. Stoddard (1931) gives a general summary of the effects produced by this species. He states: "General unthriftiness and emaciation have been reported in flocks of poultry infested with this species and with *Raillietina cesticillis.* In quail, this species may be a serious danger. There were 25 cases among birds with

bantam foster parents, where these cestodes were considered the principal or only cause of death. The average age at death was 32 days. While many recovered, if they survived to two months of age they were almost certain to be undersized, altho plumage development proceeds more normally. Quail heavily infested with these tapeworms almost invariably have their crops and gizzards crammed with food. The section of the intestine occupied by the parasites may be so distended that it is reduced to half its length, being thrown into ridges of a purplish-red color. The cestodes are under considerable pressure in the intestine, as shown by the way they "boil" out at the smallest cut. The lining of the intestine frequently sloughs off in bad cases. Occasionally all passage of food through the intestine is stopped, and sections of the cestode fragments are found adhering to the intestinal wall. In several instances, bobwhites heavily infested with this species developed trouble with their locomotion, a partial paralysis being evident."

The only other parasite found during the survey which might be considered potentially dangerous is *Eimeria.* This coccidium is undoubtedly a dangerous parasite. It is an intracellular parasite, developing chiefly in the epithelial cells of the small intestine, and when present in large numbers may give rise to acute enteritis, causing denudation of the intestinal epithelium, consequent digestive derangements and malnutrition, and the bird becomes emaciated and anemic.

Altho coccidiosis was not found in young birds, this was probably due to their age, all the chicks caught having been younger than 10 days. The parasite, however, was found in 29 per cent of the grouse examined during the season 1934-35. Bump (1935) in an examination of 169 birds ranging in age from three hours to three months reports coccidia as very common.

Coccidiosis was one of the diseases considered responsible for the "grouse disease" in England by Leslie and Shipley (1911); in Norway, by Brinkman (1927), who reported a 75 per cent infestation in young birds and 49 per cent in adults. Portal and Collinge (1932) also reported this as one of the two infections causing partridge disease in England.

It has long been maintained by many workers that the presence of parasites reduces the weight of the birds, lowering their vitality to such a point that they are more susceptible to attacks by disease and an easy prey to predators. In comparing the weight differences in parasitized and nonparasitized birds, the birds which were infested only with *Agamodistomum sp.* or *Physaloptera larvae* were considered uninfested, because the numbers of these found were usually small and once encysted in the subcutaneous tissue or muscle they would probably produce much less effect on the host than those in the intestinal tract. In 1931-32 the number of birds examined was not sufficient to give a proper comparison. In 1932-33 the parasitized females actually averaged 26.2 grams heavier than the nonparasitized females, which is contrary to what one

might expect. The parasitized males, however, were 44 grams lighter than the nonparasitized males. In 1933-34 and 1934-35, during which time parasitism was approximately 23 per cent greater than in 1932-33, a very definite weight difference occurred, both the parasitized males and females being considerably lower in weight than the nonparasitized. Altho this weight difference appears to have been due to the presence of intestinal parasites, a definite conclusion cannot be made since there are many other factors such as disease, food supply, and age which must be taken into consideration.

CORRELATION BETWEEN PARASITISM IN THE RUFFED GROUSE AND METEORO-TOPOGRAPHICAL FACTORS

There appear to be three possible causes to explain the parasitic distribution within the three zones covered by the survey. These are population numbers, intermediate hosts, and meteorological and topographical factors. All three are no doubt responsible to some extent.

What effect bird population numbers have on the infestation by parasites is not known, except that in general parasites increase with an increase in the bird population. No bird census has been made covering the state, and therefore a correlation cannot be made between parasitism and bird numbers. The State Department of Game and Fish has, during the last year, plotted the relative numbers of birds found in various parts of the state, but this map cannot be used because actual bird numbers are not reported, only whether the birds were scarce, average, or plentiful. The number recorded as plentiful in one locality may be considered scarce in another.

So little is known about the intermediate hosts and their distribution that no correlation can be made between the distribution of the intermediate hosts and the degree of parasitism in the birds. The parasites of the ruffed grouse, in which an intermediate host has been demonstrated, are as follows:

1. *Cheilospirura spinosa.*—Intermediate hosts, *Melanoplus femur-rubrum* and *M. differentialis.*

2. *Davainea proglottina.*—Intermediate host in North America, *Agriolimax agrestis* (slug).

3. *Raillietina tetragona.*—Intermediate hosts, *Helix sp.* and *Musca domestica.*

4. *Choanotaenia infundibulum.*—Intermediate host, *Musca domestica.*

5. *Oxyspirura mansoni.*—Intermediate host, *Pycnoscelus surinamensis.*

Melanoplus femur-rubrum is typically a northern form, and *M. differentialis* is a southern form. Within the limits of the present survey *M. femur-rubrum* would be the most important, but no figures are available on the numbers present in the various counties. Nothing is known with regard to the distribution of the slug *Agriolimax agrestis.* The distribution of *Musca domestica* probably would depend more upon the

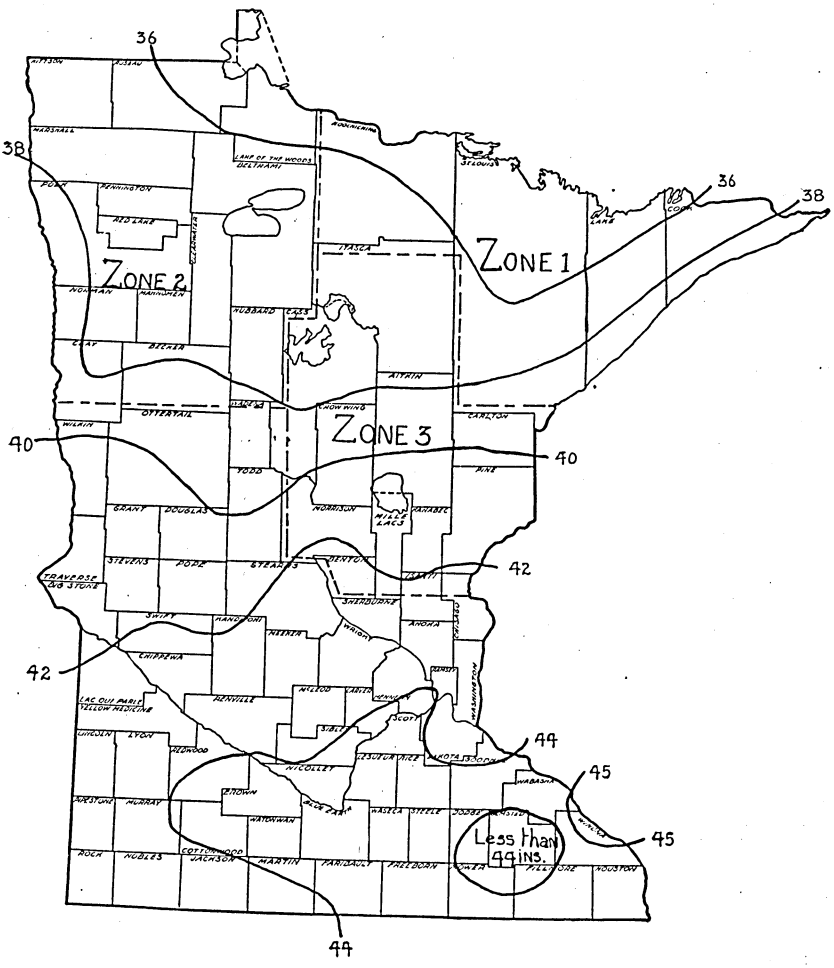
distribution of horses in the state than anything else, since they prefer to breed in horse manure. *Pycnoscelus surinamensis* is not recorded for Minnesota, so that in all probability one or both of the common forest cockroaches in Minnesota, namely *Parcoblatta virginica* and *P. pennsylvanica,* serve as intermediate hosts.

The third cause, meteorological and topographical factors, is in the writer's opinion the most important. It is well known that the ova of many parasites when outside the host require moisture before development can proceed. Lack of moisture, on the other hand, reduces or prevents development, and after a limited time the ova may fail to hatch even when placed in a suitable environment. In addition to moisture, other important factors affecting the percentage of ova that hatch are temperature, type of soil, and vegetation.

Many of the early workers realized that the ova of various roundworms can withstand long periods of dessication and extreme temperature changes. Verloren (1854) found that ova of *Ascaris marginata (Toxacara canis)* remained alive for more than a year in water. Davaine (1863) found that ova of *Ascaris lumbricoides* remained viable for five years. Brown (1927) found that development of the ova of *Ascaris lumbricoides* depended upon the type of soil, moisture, and sunlight. Ova in sand cultures exposed to full sunlight disintegrated before reaching the embryo stage, while those in clay, loam, or humus under like conditions became embryonated. Caldwell and Caldwell (1928) found that ova of *Ascaris lumbricoides* on different types of soil disintegrated in three days on exposure to full sunlight, while under shade conditions they were viable more than a month later. Owen (1930) found that the ova of *Toxacara canis* in sand, clay, and humus soils exposed to full sunlight disintegrated before reaching the embryo stage. Under part shade conditions a maximum of 18 per cent reached the embryo stage in sand, as compared to 53.5 per cent in humus. After 14 days' exposure only 5 per cent were viable in sand and 30 per cent in humus. In the case of Strongloid larvae, experiments carried out by Stoll (1923) showed that the greater numbers of *Ankylostoma* and *Necator* larvae were produced from a given amount of fecal material when the nematodes were cultured in humus, and lesser amounts were produced in sand, loam, and clay, providing moisture and temperature conditions were equal.

These experiments show, then, that the development of nematode ova depend upon a number of physical factors, the most important of which are moisture, type of soil, temperature, and coverage.

The factors which affect the development of ova of the parasites of ruffed grouse are no doubt the same as those already discussed for other genera and species. Even when an intermediate host occurs, one would expect that development of the ova outside of the host would be necessary, before development could take place, in the intermediate host. The writer believes that the meteorological and topographical factors do not favor ova development equally in different parts of the state and regards

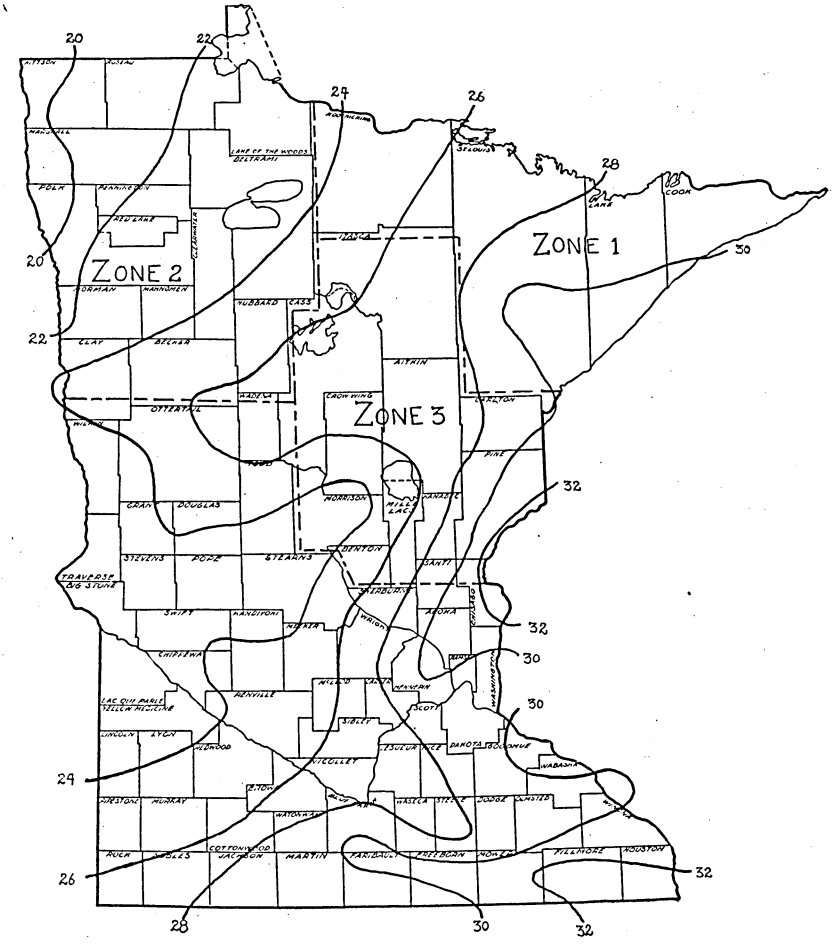


MAP 1. AVERAGE ANNUAL PRECIPITATION FOR MINNESOTA (AFTER U. G. PURSSELL)

such factors as the most important in the distribution of the parasites of the ruffed grouse.

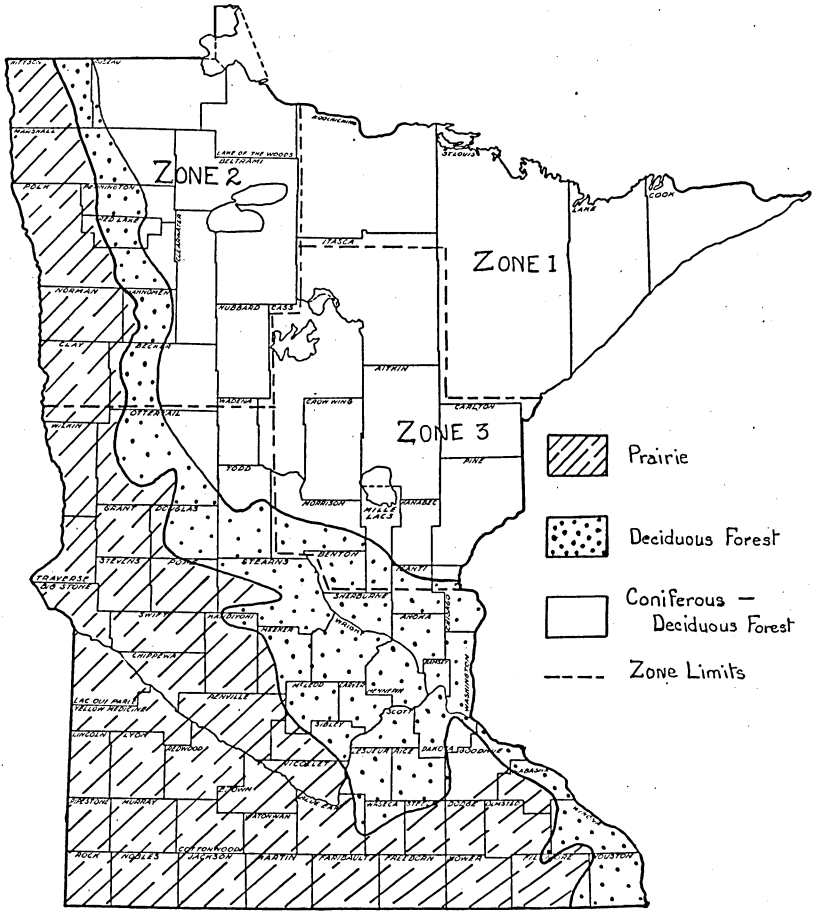
In determining the relation of the physical factors to the percentage of infestation, it must be remembered that rainfall and temperature over the area are much more uniform than are the types of soil and vegetation, which may vary considerably even within a small area. The descriptions and percentages given for the different types of soil in the various zones are very general. The important factor with regard to the soil is its ability to retain or lose water.

The average annual precipitation of Minnesota is 27.74 inches. The geographical distribution of the average annual precipitation is shown



MAP 2. MEAN ANNUAL TEMPERATURES OF MINNESOTA, DEGREES FAHRENHEIT (AFTER U. G. PURSSELL)

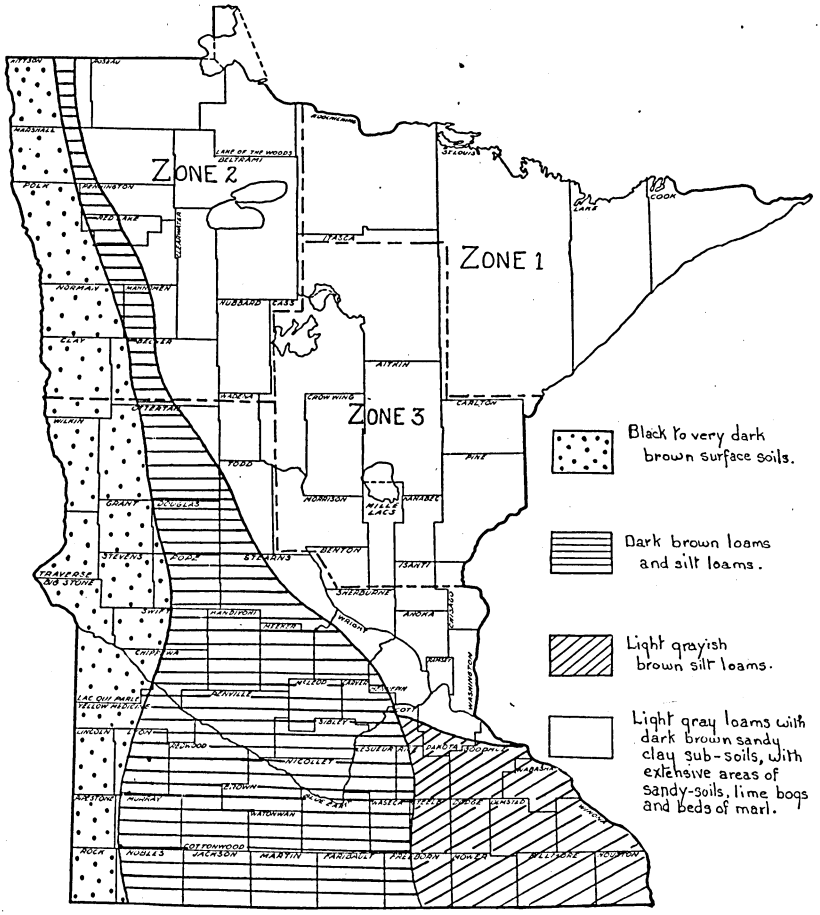
in Map 1. From this it may be seen that the precipitation is about one-fourth to one-third greater along the eastern boundary of the state than along the western boundary. The precipitation increases from the northwest to the southeast. The average annual temperature of the state is 41.7° F. The geographical distribution of the average annual temperature is shown in Map 2. The coverage in the state consists of three main types (Map 3)—a prairie area lying along the western border of the state and extending almost to the eastern boundary in the southern part, and a narrow belt of deciduous forest lying between the prairie and the coniferous-deciduous forest which occupies the northwest corner of the state. The condition of the soil depends to some degree upon the character of the vegetation which has covered it, and in general three



MAP 3. DISTRIBUTION OF FOREST AND PRAIRIE FOR MINNESOTA (AFTER WARREN UPHAM AND FREDERIC K. BUTTERS)

main types of soil correspond to the areas covered by the three principal types of vegetation (Map 4). The soil in the prairie region is black to very dark brown, with very heavy calcareous subsoils. The deciduous forest area consists of dark brown loams and silt loams with calcareous yellow-brown subsoils. The coniferous forest area consists of a relatively small part of light-colored sandy soils with coarse subsoils, and the larger part consists of light gray loams with dark brown sandy subsoils, and extensive areas of peat.

Zone 1, in the northeast corner of the state, lies entirely within the coniferous-deciduous forest. The precipitation varies from 26 inches in the western part of the zone to 30 inches in the eastern part. The average annual temperature varies from 35° F. in the north to 38° F. in the southern portion of the zone. The area is composed of approximately



MAP 4. DIFFERENT SOIL TYPES OF MINNESOTA

35 per cent lakes and swamps and 30 per cent rock. The remainder of the area is composed principally of stony loam and lesser amounts of gravelly beaches, moraines, fine sand, and lake-washed drift with a clay loam soil. The sandy and loose-textured soils are covered largely by pine forest, while the clayey or heavier classes of soil usually carry a mixed growth of deciduous as well as coniferous trees.

The factors in this zone which favor the development of ova are rainfall and vegetation. Type of soil in this particular zone is, however, the controlling factor. The sandy and rock areas which occur in this zone are very well drained, and evaporation takes place rapidly so that conditions are only favorable for ova development for a short time after rainfall. The view that this zone is unfavorable for ova development is supported by a low percentage of parasitic infestation for the total period

of the survey, during the four separate periods of the survey, and in general for the three most common species found. (See Tables 7, 8, 9, and 10.)

Zone 2 lies in the northwest part of the state. The western part of this zone is prairie and deciduous forest, with the eastern border consisting of deciduous-coniferous forest. The average annual precipitation varies from 20 inches in the western part of the zone to 26 inches in the southeastern part. The average annual temperature for the zone varies from 36° F. to 39° F. The area within this zone from which birds were examined is composed of approximately 18 per cent black clay and clay loam; 16 per cent stony or pebbly sandy loam, lake-washed drift; 30 per cent stony clay loam, lake-washed drift, and 23 per cent swamp and lake.

The rainfall in Zone 2 is considerably lower than in Zone 1. The soil in general has a much heavier texture than that of Zone 1. The occurrence of deciduous forest with small amounts of coniferous forest over most of the zone indicates that the top soil of this zone contains more humus than the soil of Zone 1.

Altho the zone has a much lower rainfall than Zone 1, the texture of the soil in general is such that it retains the moisture in larger amounts and longer than the soils of Zone 1. The richer soil conditions and the greater amount of humus provide more favorable conditions for ova development than Zone 1. This is supported by an increase in the percentage of parasitic infestation over Zone 1 for the total period of the survey, during the four separate periods of the survey, and in the cases of the three most common species found. (See Tables 7, 8, 9, and 10.)

Zone 3 occupies the middle eastern portion of the state. The whole area is covered by coniferous-deciduous forest. The average annual precipitation varies from 26 inches in the northwest corner of the zone to 32 inches in the southeast corner. The average annual temperature varies from 37° F. in the northern part of the zone to 42° F. in the southern part. The area is composed of approximately 30 per cent clayey to stony loam, 15 per cent stony loam soil, 12 per cent sandy to gravelly loam, 8 per cent sandy or gravelly areas, and 20 per cent lakes and swamps.

All factors in Zone 3 appear to be more favorable for ova development than in the other two zones. In this zone the average annual precipitation and temperature is higher than in Zones 1 and 2. The soil is mainly of a loamy nature which retains more moisture than the soils in Zone 1 and in general as much as the soils in Zone 2. All factors in the zone therefore appear to favor the development of ova, and this is supported by a decided increase in the percentage of infestation for the total period of the survey, during the four separate periods of the survey, and in the cases of the three most common species found. (See Tables 7, 8, 9, and 10.)

DISCUSSION

In general, the precipitation in the area covered by the survey increases progressively east and south from the northwest corner, a minimum occurring in Zone 2 and a maximum in Zone 3. Temperatures, in general, increase from north to south.

The occurrence of a considerable amount of moisture, which appears to be the main climatic factor favoring helminth infestation, may be brought about by one of several factors—a heavy annual precipitation, the presence of a large amount of vegetation which would tend to conserve the moisture in the soil when the mean precipitation is low, and a heavy soil type.

There appears to be a definite correlation between the incidence of helminth infestation and the mean precipitation, mean temperature, soil type, and vegetation.

Incidence of infestation appears to be at a minimum in Zone 1, where the surface soil is sandy, and at a maximum in Zone 3, where the surface soil is composed largely of loam.

The incidence of infestation which is greater in Zone 2 than Zone 1 is explained by the fact that the surface soil in Zone 2 is more favorable for ova development.

The absence of *Ascaridia galli* in Polk and Roseau counties may be due to the killing effects of direct sunlight on the ova, while in Cook and Lake counties the sandy texture of the soil may not retain sufficient moisture to allow ova development to take place.

The same factors which control the distribution of *Ascaridia galli* may also control the low infestation or absence of *Cheilospirura spinosa* in Polk, Roseau, Lake, and St. Louis counties.

The physical factors discussed are considered the most important, because no matter how numerous the birds and intermediate hosts might be, if the factors governing the development of ova outside the host are not favorable, then no parasitism will occur.

SUMMARY AND CONCLUSIONS

The present parasitological survey of 560 ruffed grouse and 62 sharp-tail grouse was restricted mainly to the state of Minnesota, from which 546 birds were examined. The remaining 72 specimens were received from Michigan, Wisconsin, and South Dakota.

In Minnesota an increase in the total percentage of infestation of the ruffed grouse has taken place from a low of 36.54 per cent in 1931-32 to 73.79 per cent in 1933-34. This increase in infestation also follows roughly for the individual species of parasites found. In 1934-35 the total infestation appeared to drop to 59.43 per cent. This decrease in infestation has been shown to be due to a distribution of the parasites in the state rather than an actual drop in the degree of parasitism. More birds were received from areas of low infestations during 1934-35

and consequently affected the total percentage of infestation for that period, but by comparing the infestation in any one area in the state, during the different periods of the survey, it is evident that the percentage of infestation remained at the same high level during 1934-35 as during 1933-34.

Sufficient numbers of sharp-tail grouse were not examined, during different periods of the survey, to enable any accurate analysis of the infestation to be made.

A comparison of state infestation was possible only during the period 1933-34, when the degree of parasitism varied considerably. The difference in the degree of infestation between the three states of Michigan, Wisconsin, and Minnesota is in all probability due to a parasitic distribution similar to that which occurs in Minnesota.

By comparing the degree of infestation in different parts of Minnesota, three arbitrary zones were mapped: Zone 1, in the northeast corner of the state; Zone 2, in the northwest corner of the state, and Zone 3, in the central eastern part of the state. Total infestation for the entire period of the survey was higher in Zone 3 than in Zone 2 and higher in Zone 2 than in Zone 1. Total infestation, except in one case, for each period of the survey was higher in Zone 3 than in Zone 2 and higher in Zone 2 than in Zone 1. In any one zone, except in two cases, there was an increase in the total infestation in each succeeding period of the survey. The same conditions apply, in general, to any of the individual species of parasites found as to the total infestation.

No seasonal variation in the degree of parasitism was found to occur.

Infestation by species of *Eimeria* was very spasmodic during the different periods of the survey. The maximum infestation (28.87 per cent) was found to occur during the period 1934-35.

Infestation by *Raillietina tetragona* in young grouse was found to occur in birds as young as four days old, and by *Ascaridia galli* in birds eight days old.

Ascaridia galli, Cheilospirura spinosa, Raillietina tetragona, and species of *Eimeria* may be considered as potentially dangerous parasites of the grouse in Minnesota, altho none of the large number of specimens sent in have shown a pathological condition as a result of the parasites. The weight difference between the parasitized and nonparasitized birds has become more pronounced during the last two years, when the total percentage of infestation reached 80 per cent. There are so many factors which may play an important rôle in determining the weight of a bird that, until further work has been done, it is best that no definite conclusions be made. The writer feels reasonably convinced that the parasites found during this investigation were not responsible for the decline in the adult grouse population recorded in the state during the summer of 1933.

In the case of the ruffed grouse, a definite correlation between the degree of parasitism and the meteorological and topographical factors

appears to occur. Infestation in the different zones outlined appears to depend upon the mean temperature, mean precipitation, soil type, and coverage, the maximum infestation taking place where the mean temperature and precipitation are highest, where the humus content of the surface soil is greatest, and where abundant coverage occurs.

The correlation found to exist between parasitism in the ruffed grouse in Minnesota and meteoro-topographical factors compares very favorably with the findings of a similar survey by the writer (1933) on the snowshoe rabbit *(Lepus americanus)* carried out in the Province of Manitoba, Canada, during the years 1930-1932.

In the writer's opinion, none of the parasites found during the present survey (which does not include examinations of adult grouse during the months of June, July, and August) have been directly responsible for the mortality among the *adult* ruffed grouse during the year 1933-34; when a decrease in the grouse population was reported. Certainly an increase in infestation has taken place during the four periods of the survey, and a maximum has been reached at a time when the birds were reported to be dying off. Even at the time of maximum infestation, the writer does not believe that sufficient numbers of parasites were present to cause the death of any of the birds examined. Those birds, where maximum numbers of parasites were found, appeared to be normal, healthy specimens. All cases of infestation by *Eimeria* were of a mild type. Whether an increase in parasitism does take place during the summer months is as yet unknown, so that the possibility still exists that parasitism is the cause of "epidemics" in adult grouse during the summer months. It is probable that the increase in parasitism would not have to be much greater than that occurring in 1933-34 or 1934-35 before a definite pathological condition would occur.

That the parasites have played a secondary part in the death of the birds is probable. Accompanying the increase in infestation, there has been a definite increase in weight difference between parasitized and nonparasitized birds. The parasites may have played a part in reducing the vitality of the birds to a point where secondary diseases could set in.

It appears more probable to the writer, however, that any mortality that did take place might have occurred in the young grouse. The occurrence of such a dangerous parasite as *Raillietina tetragona* in birds four days old suggests that many of them die as a result.

During the total period of the survey, there have been no reports of a complete wiping out of the grouse in any one locality, nor has there been any definite evidence of an epizootic. If the adult grouse population died off at a *normal* rate, there would be considerably fewer birds in the fall than in the spring. This drop in population in normal years is not noticed, because the birds hatched in the spring have grown to a large enough size by September to replace them. If, however, the young birds are killed by parasites, disease, or some other factor, then a drop in the grouse population is immediately noticed. The occurrence of parasites

at such an early age in the young grouse suggests that many of them are killed by parasites before they reach maturity, altho no proof exists to show that a greater percentage of them die off during years of decline in grouse population. It is evident that a slight increase in the total percentage of parasitic infestation might easily affect the young grouse without producing any great effect in the adult birds. These conclusions indicate the definite need for further investigation and the possibilities of establishing the causes of mortality in young grouse from the time of hatching to September.

Considering the wide area covered by the survey, the number of birds examined was small. Percentages of infestation have, in many cases, been based on a small number of birds. To justify definite conclusions, it would be necessary to perform autopsies on many thousands of birds, but the writer publishes the information available, with the hope that it may lead to further developments.

The conclusions put forward in this bulletin indicate the need of further investigation, particularly during the summer months and among young grouse.

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